

DesignThinking

Practical Introduction:

New product development,

3P (Production Preparation Process)

*& SMED-Design-Thinking Workshop
(Single Minute Exchange Process)*

Edition 2020a

Eduardo L. García



Factory Management Institute

COOPERATING TO REACH EXCELLENCE



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DesignThinking

Practical Introduction: New product development, 3P (Production Preparation Process) & an SMED Workshop

Author: Eduardo L. García. Sensei-1^{er} Dan, Factory Management Institute. Junio de 2020.

Abstract: *Logical and predictable gradual innovation has become a weapon that any company can exploit and its competitive advantage is no longer relevant. However, groundbreaking innovation, which does add value to users and that we can't even imagine now, is the innovation that companies need to compete in this new globalized environment. But no one sees these innovations until someone shows them.*

Thus, the question is how to innovate and how to do it repeatedly, as a form of business strategy. The technique baptized by the IDEO company, as "Design + Thinking" is the technique that encourages and develops these groundbreaking innovations through GAMES of "Brain-Games" sessions or various techniques known as Brainstorms or Brainstorming. That same techniques can be used to face innovative solutions in solving day-to-day problems of any work group in the company, even within the Quality Control Circles or multifunctional work groups.

This manual shows an example of possible innovation via on a user or product experience and also on a SMED (Single minute Exchange of Die) workshop applied to a production process in industry and its development in 3P (Production Preparation Process).

Key words: Design-Thinking, SMED, Single Minute Exchange of Die, 3P, Production Preparation Process, Brain-game, Factory Management Framework, Excellence, Lean Manufacturing.

Sinopsis: *La Innovación gradual lógica y previsible se ha convertido en un arma que cualquier empresa puede explotar y su ventaja competitiva no es ya relevante. Sin embargo, la innovación rompedora, que sí agrega valor a los usuarios y que ni siquiera podemos imaginar ahora, es la innovación que precisan las empresas para competir en este nuevo entorno globalizado. Pero nadie ve estas innovaciones hasta que alguien las muestra.*

Así, la cuestión es cómo innovar y cómo hacerlo repetidamente, como una forma de estrategia empresarial. La técnica bautizada por la compañía IDEO, como "Design+Thinking" es la técnica que fomenta y desarrolla estas innovaciones rompedoras mediante sesiones de JUEGOS de "Brain-Games" o diversas técnicas conocidas como Tormentas o Lluvias de Ideas. Esa misma técnica se puede utilizar para enfrentar soluciones innovadoras en la resolución de los problemas en el día a día de cualquier grupo de trabajo en la empresa, incluso dentro de los Círculos de Control de Calidad o grupos de trabajo multifuncionales.

En este manual se muestra un ejemplo de posible vía de innovación sobre una experiencia de usuario o producto y, también, sobre un taller SMED (Single minute Exchange of Die) aplicado un proceso productivo en la industria y su desarrollo en 3P (Production Preparation Process).

Palabras clave: Design-Thinking, SMED, Single Minute Exchange of Die, 3P, Production Preparation Process, Brain-game, Factory Management Framework, Excellence, Lean Manufacturing.



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Within the Factory Management Institute, it holds the SENSEI 1st DAN qualification achieved in January 2020 after the publication of the research and the corresponding book, on the development of the TPS-Total Preventive Safety¹ and the previous publication of the book “The system of excellence²” and the in-company-handbook for 5S+4R deployment.



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¹ Zero Accidents, Total Preventive Safety: <https://www.amazon.com/dp/1678844209>

² The System of Excellence: <https://www.amazon.com/dp/1973409771>

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Content

I. Introduction	7
Game and Diversity	7
¿Where is Design-Thinking?	8
II. Innovation in company:.....	10
¿ Where does Design-Thinking fit into the Factory Management Framework?	11
III. The Challenge.....	13
IV. OPENING Session of Design-Thinking.....	15
Fuzzy front-end definition	16
“A” State definition	16
V. ACT ONE of the Design-Thinking session:.....	19
Opening questions to define starting point “A”	20
The Six Thinking Hats by Edward de Bono:	21
Tentative B states.....	22
VI. ACT TWO of the Design-Thinking session:.....	25
Braingames.....	26
Asking to EXPLORE (1)	27
Questions for INSPECTION (2):.....	28
Questions for EXPERIMENT (3)	28
VII. ACT THREE of the Design-Thinking session:	29
Prototype and Working Plan	30
3P and Manufacturability.....	30
3P STEPS simplified	32
Detailed steps in a 3P session	33
VIII. SMED-Workshop under Design-Thinking	35
Commercial solutions or Design-Thinking.....	35
Preparation and definition of state "A"	36
A work Agenda of the Design-Thinking session	37
Standardization of processes for the definition of point "A"	39
Definition of a in the initial state "A", of a milling machine.....	40
Process Data	43
The Traditional Thinking Model of the Manufacturing Engineering Department	44
Fuzzy front-end of what we are searching.....	45
Act One.....	46
“Brain-game” in Ext-A1 state: External measurement of the part	47
“Brain-game” in Ext-A2 state: Quick external clamping of the piece	47
“Brain-game” in Int-A3 state: Part removal and quick placement.....	47
Act Two.....	48
Process Ext.A1: Externalized Part Measurement.	49

Process Ext.A2: Quick external clamping of the piece.	51
Process Int.A3: Evacuation of the already processed part and placement of the new one, in the work area, in less than 10 minutes.	53
Act Three	56
Concretion	56
IX. Annex A: Large machining: new clamping and positioning technologies	58
Tooling, positioning and monitoring systems	58
Vertical lathes and large milling machines.....	60
Large components: Tractor sectors in our environment	60
Large vertical lathes	60
Machining centers: precision in large dimensions.....	61
Use of 'high performance computing' and monitoring of machine tools to improve competitiveness	61

Updateings table:

Date, Version, Next & Previous	Chapter (I..XX...)	Point or Sub-point in the Chapter: (Updating issue)
Rev. 1.0 a Rev.2020a	Extension of chapter II: Innovation in the company, Factory management framework and Design-Thinking	Where does Design Thinking fit into the Factory Management Framework?
Rev. 1.0 a Rev 2020a	Spanish translation in Spanish version	Each and every chapter
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I. Introduction

First the successful company IDEO³ and later many other scholars, have developed a multitude of techniques to innovate that can be included in what IDEO called **Design-Thinking** or **H2H** or "**Human Centered Design**"⁴.

"Design Thinking is a human-centered approach to innovation that relies on the designer's toolkit to integrate the needs of people, the possibilities of technology and the requirements to achieve business success"

Tim Brown, President and CEO of IDEO

In this reading, only some of these most common and useful tools or "Games" will be named. As well as the fundamentals of the methodology are detailed, without pretending to cover the totality of this knowledge, but simply to provide a guide for its practical introduction in the process improvement groups and, even, in the Quality Control Circles that can be built in the **Production Gemba**.

This tool is designed to generate "groundbreaking" and different ideas. These ideas can be developed for the improvement of the company's processes, the same business strategy, in the development of its products or, even, new ideas aimed at its own workers, customers, suppliers and the same society as a whole, under the commitment 3S as the fundamental condition in the searching of excellence.

This tool can also be used within the culture of continuous improvement or **Kaizen**, which is so difficult to implement in Western organizations. Although, it is not a technique or a tool of Japanese origin, but from Silicon Valley in the USA and perfected in the innovative environment of the San Francisco area in California.

Game and Diversity

Within this methodology, "The game" is established as the best environment for generating ideas. An informal, flexible, visual, fun and ultimately motivating environment. Good ideas come from good humor, jokes, and even ridiculing certain situations.

In these Games, the quality of the ideas does not matter, but the quantity. Thus, an apparently "ridiculous or funny" situation may lead us to discover needs or approaches that were hidden before.

For the development of these sessions, in the formation of the group the diversity of thoughts, origins, ages, genders will prevail and not so much the experience in the subject that develops the work session. This approach is a fact demonstrated by several scientific studies related to the innovation capacity of "Diversity Groups"⁵

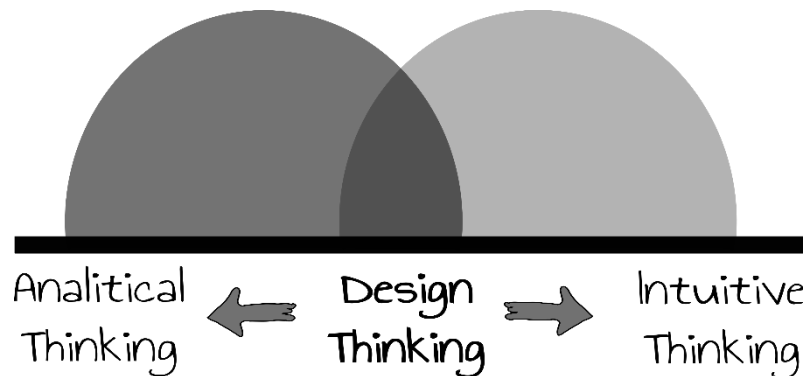
³ IDEO: IDEO is pronounced as "EYE-dee-oh: <https://www.ideo.com/about>

⁴ **Design Thinking:** <https://www.innovationtraining.org/steps-to-design-thinking/>

⁵ **Harvard Business Review, How Diversity Can Drive Innovation:** <https://hbr.org/2013/12/how-diversity-can-drive-innovation> Global Diversity and Inclusion. Fostering Innovation Through a Diverse Workforce https://images.forbes.com/forbesinsights/StudyPDFs/Innovation_Through_Diversity.pdf

¿Where is Design-Thinking?

Unlike traditional thinking that solves problems through Analytical Thinking, **Design Thinking** uses an approximate 50% mix of Intuitive Thinking and Analytical Thinking.



Analytical Thinking is intended to solve closed problems, or what *Gamestorming*⁶ book calls "Puzzles". Puzzles have only one solution that can be considered the best solution to the problem. It is like going from a point A to a point B for which journey premises based on Rationality, quantification, control and planning are used.

In the Journey from point A to point B there may be different methodologies, such as Project Management, DMAIC⁷ cycle from the (6σ) Six-Sigma methodology, etc. Let's imagine, for example, a PERT⁸ chart and that could be the image of analytical or scientific thinking.

In contrast, Intuitive Thinking is erratic, primarily motivated by inspiration or chance. It is the image that we could all have of a "genius of ideas" or the typical image of a "wacky inventor." Between these two modes of thought is Design Thinking, which navigates between the two modes of thought and work, appropriating the best of both perspectives.

This thinking model allows everyone to generate new and revolutionary ideas, designs, models or systems. Not only for "genius", although for this "genius", *Design Thinking* facilitates access to a new stage of thought to generate even more and better ideas.

Design Thinking aims to solve problems whose goal is diffuse or is not known. This type of problem, in contrast to puzzles, could be called "Mystery".

In the journey from point "A" to point or fuzzy goal "B", the journey is based on Observation, Experimentation, Intuition, Abstraction, Divergence and a certain measure of Chaos. In the "Puzzles" we look for the best solution, although this is always subjective. But in the "Mysteries" we look for good or better answers, without restrictions and with "child's eyes". If we start working with thought restrictions, the result will always be predictable.

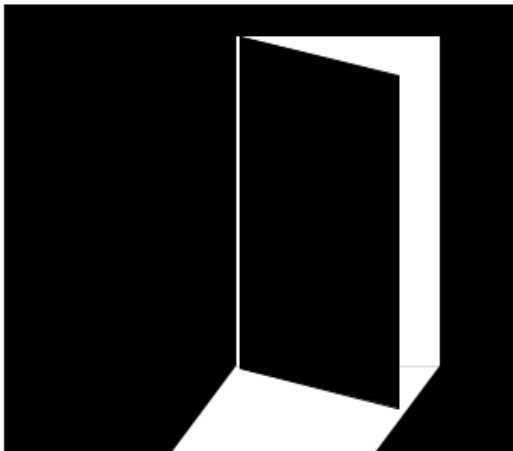
⁶ **Game Storming:** ISBN-10: 842340966X / ISBN-13: 978-8423409662

⁷ **DMAIC:** <https://en.wikipedia.org/wiki/DMAIC>

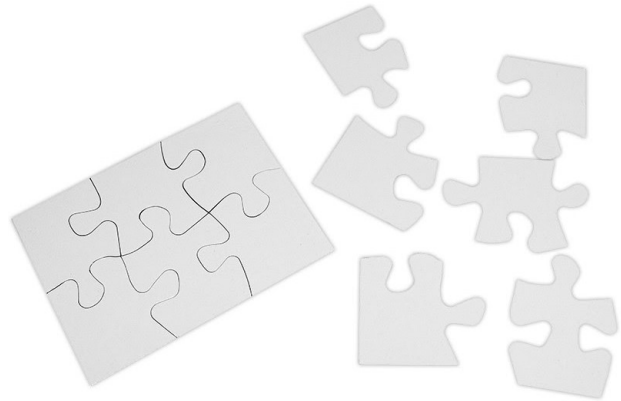
⁸ **PERT:** Program evaluation and review technique.

https://en.wikipedia.org/wiki/Program_evaluation_and_review_technique

MISTERY



PUZZLE



In this way, Design Thinking generates unpredictable, unpredictable, surprising and innovative results, through a methodology of exploration and discovery.

II. Innovation in company:

In the past and even in the present, the scientific perspective has tried to dominate the management of companies. Rationality, logic and statistical analysis serve to control and facilitate the management of companies. All decisions are based on past data or references to the past to justify future decisions.

"The past can help us understand the foreseeable future, but disruptive innovations do not emerge from past data. The competition can easily use the same techniques to reach similar and totally predictable solutions"

Gabriel Simonet⁹

Now and every day to a greater extent, innovation becomes an essential and strategic resource for companies in their search for excellence and an innovation that provides value, a disruptive innovation.

Innovation can be applied, not just to products, as we can all imagine, but to processes, management and strategy, personal relationships, even in the way the company calculates or considers personal efficiency. That is, it can be applied to any type of problem or challenge.

Innovation becomes a strategic corporate resource and must be integrated into the daily management of the company. Within the motto that bases the Factory Management¹⁰ by the Factory Management Institute; "**All people's participation**" can be integrated into the sporadic work of QA circles, new product design groups, or even annual corporate policy planning. It can even be applied, as we will see later to a SMED (Single Minute Exchange Die)¹¹ workshop

To better understanding about the process determined by Design Thinking, we are going to use a practical example and think about an innovation process for a common product that we all consider immovable, to date, which are cans and containers of paints or similar products. Then the idea of the SMED workshop will be taken up again on a 3-axis milling machine.

But first we will try to fit this "new" tool into the corporate development structure that represents the Factory Management Framework created by **Sensei** Koichi Kimura as a corporate management development framework that allows structuring the search for excellence, balancing and balancing two novel concepts: **Leftware** and **Rightware**, each associated with their respective abilities in each brain hemisphere; The Left refers to the management techniques and tools or "Hard-Skills" and the right to the so-called "Soft-Skills".

⁹ Gabriel Simonet. <https://www.linkedin.com/in/gsimonet/?originalSubdomain=uy>

Design Thinking como estrategia. El caso IDEO (Spanish):

https://www.academia.edu/4969244/Design_Thinking_como_estrategia_El_caso_IDEO

Modelos para la Innovación, el Caso IDEO (Spanish):

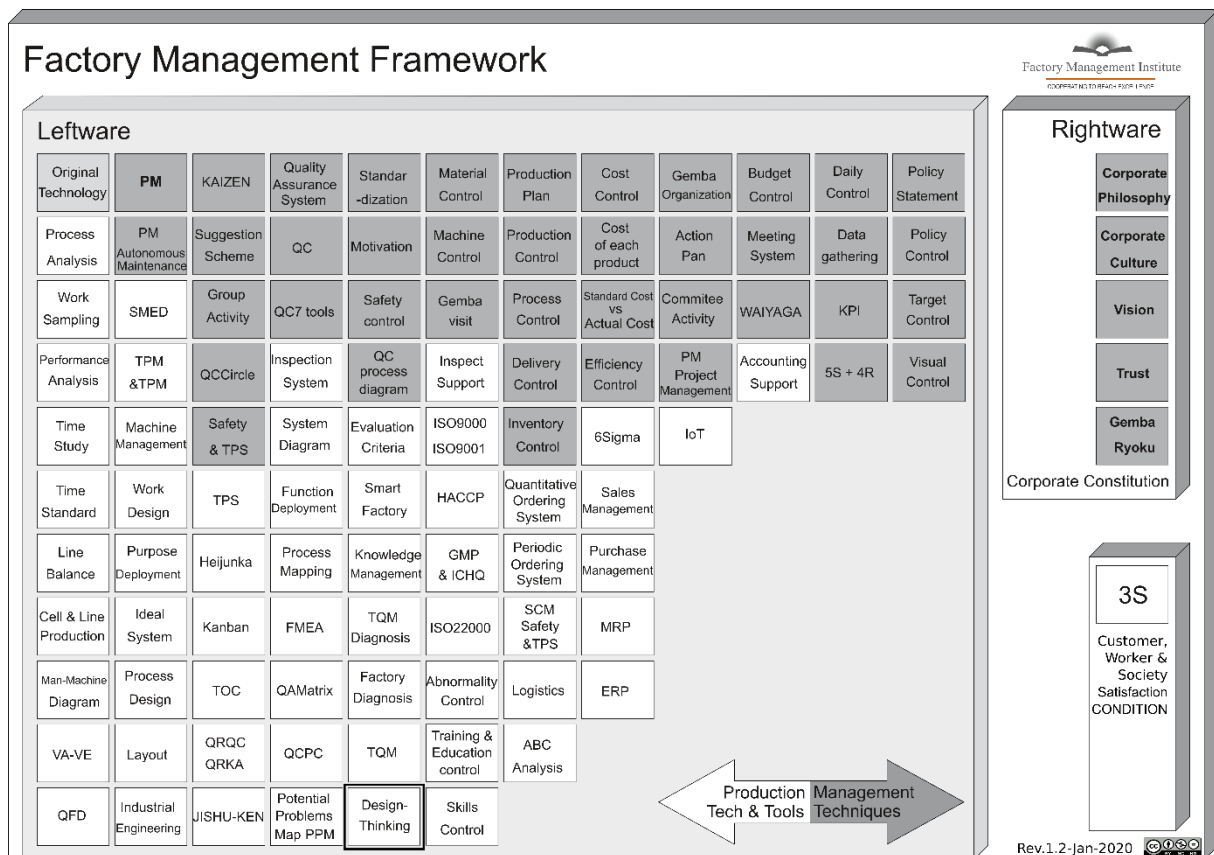
https://www.academia.edu/13147602/Modelos_para_la_Innovaci%C3%B3n_el_Caso_IDEO

¹⁰ The System of Excellence: Amazon ISBN-13: 978-1521901861 / ISBN-10: 1521901864

<https://www.amazon.es/dp/B0744PTWF4> <https://www.amazon.com/dp/1521901864>

¹¹ SMED (Single Minute Exchange of Dies): https://es.wikipedia.org/wiki/Single-Minute_Exchange_of_Die
https://en.wikipedia.org/wiki/Single-minute_exchange_of_die

¿ Where does Design-Thinking fit into the Factory Management Framework¹²?



This tool is a **TECHNICAL TOOL** belonging to the **Leftware**, which would appear among those shown with a white background and also within the tools that could develop the Original Technology that, the SELVEDGE represents the fabric of the “Factory Management Fabric”¹³.

It is also part of the **CULTURE OF THE COMPANY** belonging to **Rightware** and the habits of the group when solving a problem, as mentioned above regarding the IDEO company within whose culture this strongly developed tool is found.

It has been mentioned that **Design Thinking** is a special way of dealing with the resolution of a problem, such as VA-VE¹⁴ or Production System or TPS represented by the House of TPS that **Sensei**

¹² “Factory Management Framework” or “House of Lean” <https://www.slideshare.net/enateduardo/the-house-of-lean-v37-elg> : I must admit that my initial attempt to group the technical and management tools in the format that I initially called ‘House of Lean’, and of which I made four versions, I now consider an absolute failure, even when Japanese companies such as HITACHI or prestigious consulting firms are used for their workouts: <https://www.slideshare.net/KeithBrown35/sc-manufacturing-conference-and-expo-hitachi-i-iot-april-20-2016-final> y <https://strategyassociates.cc/on-the-lean-organization/> . Please, definitely forget this format, although it has been distributed to such an extent that the damage has already been done and there is no remedy, so I will try to amend it by creating a new updated version 4.0 during the next months of this 2020 ”.

¹³ **Factory Management Fabric:** <http://factorymanagementinstitute.com/wp-content/uploads/2018/10/The-Cloth-of-Management.png>

¹⁴ **VA-VE:** <https://www.youtube.com/watch?v=dvdfxr0fMzs>
https://es.wikipedia.org/wiki/Ingenier%C3%ADA_del_valor

Taiichi Ohno once represented. However, it is not part of this grouping of tools represented in the Factory Management Framework, no doubt because it is a relatively new tool in corporate management and strategy.

Factory Management Framework has had to be expanded and modified to a version 1.2 of January 2020, with this new tool. Because it doesn't really fit into any of those depicted in its original version created by *Sensei* Koichi Kimura.

This tool can also be used, for example, in group work facing a SMED challenge, in order to go beyond the original approach of achieving the die / tool / holder change in less than 10 minutes. This tool encourages thinking outside the box, so new perspectives may emerge suggesting breakthrough solutions.

In this way, above chapter is dedicated to an example of application of this for a development of a quick change of support in a milling machine.

https://en.wikipedia.org/wiki/Value_engineering

<https://www.slideshare.net/thombremahesh/value-engineering-and-value-analysis>

<https://www.slideshare.net/gazwsxedcrfvtgbyhnujmiko/value-analysis-and-value-engineering-17040020>

III. Challenge

In this challenge we set out to modernize the way in which, for example, paintings are packaged to improve the user experience throughout the painting process, from purchasing the paint, to transporting and painting, as well as the labor cleaning waste and other accessory work in the process.

In the illustration on the next page, we can see that initially the cans were made of steel in the shape of a cylinder, then plastic, later different gadgets are created to improve the user experience (Painter's Kit, etc.). Now a series of rectangular plastic containers has been developed, which better adapt to the shape of the rollers, being a container with great acceptance and used mainly in painting work at home.

Even so, problems persist, such as dripping from the roller when it comes out of the can, and it is necessary to shake it vigorously, with the consequent risk of projecting the drops or, rolling the roller on a surface that removes excess paint. In other words, the user experience is not completely satisfied and it seems that the price of the rectangular or, rather cubic container, is still a bit more expensive than the cylindrical one, which forces some brands to discard it in order to compete in "better" conditions, when price is the critical element.

In the focus of this illustration, it is evident that the Design Thinking technique has not been used to develop an element that contains paint and allows the applicator element to be impregnated, whatever it is; Brush; Roller or even a new element to be developed that, at this time, we do not know its name, shape and form of use or application.

Design Thinking tries to develop the user experience, even simulating it, creating prototypes or drawing it. In this way, it is possible to solve, not only a certain problem, but also satisfy the user with a product that solves their problems in a disruptive way. Problems, even we do not know that they exist when raising the challenge.

The journey we see in the illustration below is predictable, we could even predict that the next step in development is "integrating the surface to remove excess paint in the container", in some way; Inside the container; Integrated into the deck or extending in some way; etc.

This development is really complex and yet it is also predictable. Therefore, despite the possible patents, it is certain that someone is already working on this development somewhere in the world while we think about it, right now. Thus, Design Thinking tries to go beyond predictable innovation.

In this case, we could establish examples of possible solutions to this problem, But this would be equivalent to reducing the solutions to a limited range of options, within which the innovations would be predictable.

Even so, and to better explain this methodology, we will use this example in the development of this handbook. Although the final conclusions are not considered, for two reasons:

- The first one is that each group will achieve theirs and they will be very different from other groups;
- The second one is that each group practices **Design Thinking** through a real and tangible problem. In this way, this methodology will be better understood.

CHALLENGE: TO IMPROVE THE HUMAN EXPERIENCE



IV. OPENING Session of Design-Thinking

To start thinking we need a phrase, a challenge or a question. This can be in the form of "We need, we want to solve ...", "What form would it be ...", or "We want something that ...", etc. The initial question limits the solutions, so it should be as abstract as possible in its definition.

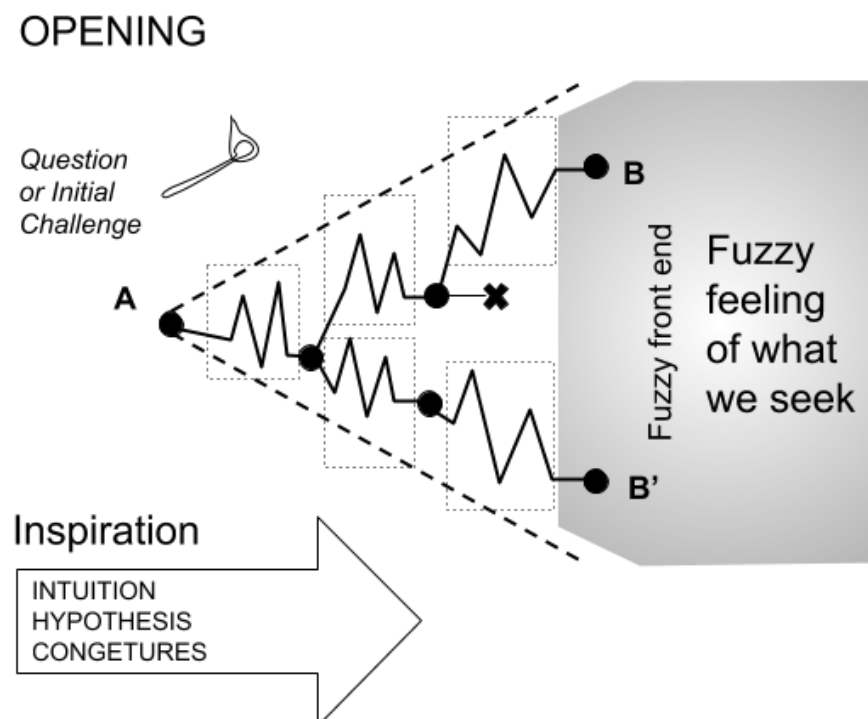
The challenge could be titled, in this case, "Painting a wall." Although, in this way, we have already described the possible solutions for the use of paint as a base to improve the appearance or renew the appearance of a wall.

Also, we could have opened up the fuzzy goal more with a less defined statement, like: "Renew the look of a wall." In this case, paint could be an option, but it could also be vinyl, siding of any kind, such as wood, tile, fabric, veneer, or we could even have questioned the construction itself or the need for the wall, with questions like "What are we going to do with this wall?" or "Why do we need a renovated wall?"

The initial question or statement of the problem establishes the limits of the innovation, so it must be as fuzzy or abstract as possible, but always within the limits of the problem we want to solve.

Even if we set a sufficiently predictable goal, like the one we are dealing with, regarding the paint container example, we can come to ground-breaking conclusions based on the initial question you define, certainly point A in the graph below.

That is, point "A" marks the beginning, the initial question marks the amplitude of the answers that we will obtain at points B and B' or any B that may arise.



In the previous figure, we can see that one of the ways of thinking taken had to be abandoned to find a "way out" or, in other words, "not to reach a result close to the solution of the initial question".

Fuzzy front-end definition

The fuzzy goals, defined by the initial question, should show what the win looks like during the process. In addition, a series of requirements are established that the final objectives must meet: they must be Emotional, Sensory and Progressive (ESP):

E-emotional; That contribute to creative projects. The goal must have a compelling emotional component.

S-sensory: Tangible objects that can be shared with the group. Drafts, Models, User Information or Consumer Experience.

P- Progressive: The diffuse objective changes with the work and travel of the group. You don't know what you don't know, so a "successive approximation" is required. The objectives may change or vary depending on what has been learned.

The fuzzy goal channels the overall direction of the work, without blinding the team to opportunities that arise during the journey. At the level of imprecision and vagueness, a certain amount of ESP is needed.

“A” State definition

In preparation for the design work session a series of information gathering activities should be carried out.

The work session should be conducted with all members who know the information available and the answers to these four basic questions:

Definition of INITIAL state "A":

1. **What do we know?**
2. **What do we not know?**
3. **Who is the team?**
4. **What are our resources?**

To obtain the information that we have and the information that we do not have, we must go to several sources:

- Experts;
- Process mapping;
- Consultation of "borderline cases" or "extreme users or early-adopters", "User experiences", "errors"
- List of...: a constant exercise of observation, for example, of user experiences, travel and mapping of alternative processes
- Do not ask, but "go and see": "Gemba attitude"¹⁵

¹⁵ Gemba attitude or Gengi-Genbutsu: https://en.wikipedia.org/wiki/Genchi_Genbutsu

- Constantly ask "why" (why, why, etc.) and in any situation: do not take any given situation for granted, do not assume the phrase "it is done this way" or "we have always done it this way": "Question everything".

For the case we use as an example, we can see on this page, how do we do the work? In addition to using expert judgment or our own experience:

- <https://www.wikihow.com/Paint-a-Wall>
- <https://www.wikihow.com/Paint-a-Concrete-Wall>
- <https://www.wikihow.com/Paint-an-Interior-Wall>

Within what we know in the initial state "A", we also have to know the existing solutions to solve the problems most similar to the problem we propose to solve, even through other means.

In this case, for example, there is a device made by Black & Decker that provides paint to the roller and, in theory, prevents dripping. However, this will not be the problem we are going to solve, as we will see later. Similar devices have also been developed by other manufacturers.

<https://www.youtube.com/watch?v=TwW8BWUDLqw>



" Fail often, to succeed sooner "

Design-Thinking as IDEO promotes

Defining the initial state "A" is a basic step in writing the initial question that allows the explosion of ideas that begins the first act of the *Design-Thinking* session.

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V. ACT ONE of the Design-Thinking session:

OPENING - INSPIRATION - IDEAS - INFORMATION - FUN - LISTENING - DEEP DIVING

In the first act, the stage is set and ideas emerge and information is shared

Requirements of the first opening act: **DIVERGENT**

- Create a pleasant environment with which people feel invited and welcome;
- Promoting creativity means not fostering, at that moment, a critical sense. You cannot be critical and creative at the same time; the mind does not work this way;
- It is preferable to ask for forgiveness rather than permission;
- The more ideas that are generated, the better;
- Create discussion spaces, modular equipment, surfaces on which you can write and write without limitations;

Personally, in my experience these environments are not common in many companies, much less in some factories. For example, where the rigid perspective of the 5S¹⁶ is applied, these environmental requirements can be difficult to implement. However, there must be room in organizations for this type of stay dedicated to "looking outside the box", in which, although the 5S-based methodology is applied, it is adapted to the particularities of "Design-Thinking"



¹⁶ **5S**: The 5S method, named after the first letter of the name in Japanese that designates each of its five stages, is a Japanese management technique based on five simple principles. The 5S integration satisfies multiple goals. Each 'S' has a particular target: [https://en.wikipedia.org/wiki/5S_\(methodology\)](https://en.wikipedia.org/wiki/5S_(methodology)). Sensei Koichi Kimura the two lectures about 5S: 5S-1 <https://archive.org/details/5s1eng>, 5S-2 <https://archive.org/details/5s2eng>

Opening questions to define starting point “A”

Opening questions can be written based on the following guidelines:

- How would we define the problem we are facing?
- What kinds of things do we want to exploit?
- What are the most problem areas?
- 5W + 2H: what, when, where, who, why, how and how much;
- What are we searching for?
- Tell user stories, user experiences (stories).
- Comply with 3S: Satisfaction of employees, customers and companies.

Therefore, the fuzzy end goal is therefore determined by the INITIAL QUESTION to define point A. In the case of the example, we will take an example question:

"How do we deposit paint in a commercial container that prevents spills and drips of traditional roller application?"

or, the keywords that define point "A":

"Commercial container that allows the impregnation of rollers without dripping".

In this way, we narrow down the problem and limit the solutions. And, although this same dimension is contrary to the philosophy of Design-Thinking, it is also necessary to define the initial state "A", to start from a situation that can be evaluated later on real data.



In the case of the previous image, the painting changes from an original container or can, to an intermediate one with an impregnation tray that prevents dripping.

This solution becomes a problem and an opportunity for improvement or product creation. The problems of this repackaging must be compiled in critical sessions or, through Edward De Bono's Six Thinking Hats in order to detail this initial "A" state.

The Six Thinking Hats by Edward de Bono:

In a prepared session and once an initial state has been defined, a work session can be carried out based on this interesting tool, in order to further detail this initial state "A" or to consider other different possible tentative states "B".

For example, in the present case and to detail the problems of the initial state "A" and to obtain possible tentative states "B" we can run this session in which each of the six members of the group wears a different hat:

- Blue hat: is the one that controls the rest of the hats; control the times and the order of them.
- White hat: to think more objectively and neutrally as possible.
- Red hat: to express our feelings, without the need for justification.
- Black hat: to be critical in a negative way and think why something could not go well.
- Yellow hat: unlike the black hat, this one tries to find the positive aspects of a certain aspect.
- Green hat: opens up creative possibilities and is closely related to your idea of lateral or divergent thinking.

Wikipedia source¹⁷

Thus, for example, the White hat is in charge of the figures or the real facts. For example; How much paint do we lose in the drip, or how much time do we spend cleaning the drips, how much paint do we waste on the roller or brush, or even, how much does all this cost? In general, the objective data of the initial state "A" and to define new states "B" based on objective considerations.

To represent these figures, it is necessary to obtain them in advance, so this session must be prepared with enough time to obtain this vision by the persons who puts on the white hat.

The session of the six thinking hats can also be prepared with a collaborative session in which all members wear the same hat color in order to establish the greatest possible breadth in each perspective.

Regarding the Red hat, it requires putting oneself in a situation, so it also requires an exercise in theoretical introspection and prior imagination to act as an end user and to empathize with it. In this

¹⁷ The Six Thinking Hats by Edward de Bono: https://en.wikipedia.org/wiki/Six_Thinking_Hats.

ACTIVITY & HAT SEQUENCE: Initial Ideas: Blue, White, Green, Blue. **Choosing between alternatives:** Blue, White, (Green), Yellow, Black, Red, Blue. **Identifying Solutions:** Blue, White, Black, Green, Blue. **Quick Feedback:** Blue, Black, Green, Blue. **Strategic Planning:** Blue, Yellow, Black, White, Blue, Green, Blue. **Process Improvement:** Blue, White, White (Other People's Views), Yellow, Black, Green, Red, Blue. **Solving Problems:** Blue, White, Green, Red, Yellow, Black, Green, Blue. **Performance Review:** Blue, Red, White, Yellow, Black, Green, Blue.

case, the red hat would evaluate emotional problems from state “A” to bequeath to new states B. Such as, for example, the annoyance of dirtying with drops or the reprimands of your mother when she sees that the corners of the floor are difficult to clean from the constant drips or the hassle of kneeling to wipe up paint drips etc. The positives, if any, should also be evaluated, not just the negatives, such as the price of a cheap solution against another that solves all problems, but is inaccessible.

The opening session would be established, for example, in the following scheme and within the perspective of the six thinking hats:

1. Day 1:
 - A. ½ hour session for the definition of the initial state “A”
 - B. ½ Hour session to define the Blue hat, to establish the methodology
2. Day 2:
 - A. ½ hour session for the White hat.
 - B. ½ hour session for the Red hat.
 - C. ½ hour session for the Black hat.
 - D. ½ hour session for the Yellow hat.
 - E. ½ hour session for the Green hat.
 - F. ½ hour session to define the tentative states “B”

The same approach can be used to refine the following states from “B” to “C”, as will be seen later.

This technique can be applied in the same session with each participant putting on a different hat, however it is somewhat less productive in practice because group collaboration allows for greater breadth in the different perspectives than just an individual.

The same approach can be used to refine the following states from “B” to “C”, as will be seen later.

This technique can be applied in the same session with each participant putting on a different hat. However, it is somewhat less productive in practice because group collaboration allows for greater breadth in different perspectives than just an individual.

Tentative B states

In the opening act we went to different fuzzy “B” possibility states:

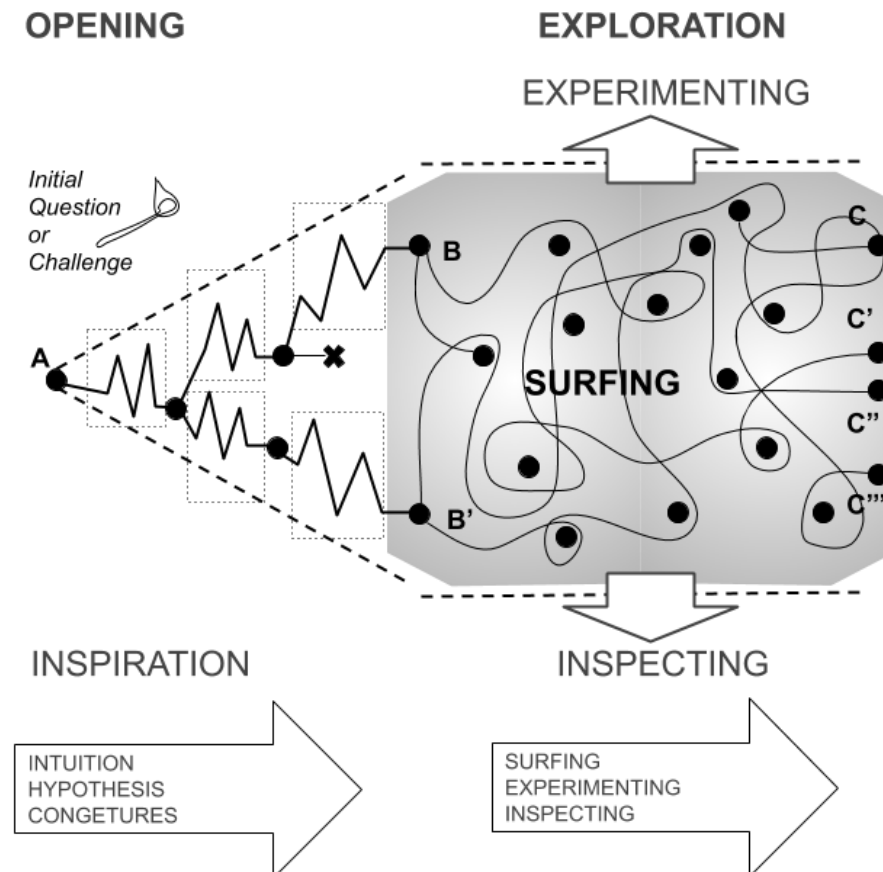
- **Tentative “B” 1:** Variations on the paint container
- **Tentative “B” 2:** Variations on the paint roller or applicator



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VI. ACT TWO of the Design-Thinking session:

IDEATION - CREATION - EXPLORATION - EXPERIMENTATION - INSPECTION.



In the second act, you **explore**, **experiment** and **inspect**. It is the true act of creating alternatives with an eye on the "fuzzy target."

Requirements of the Exploration Law: **EMERGING**

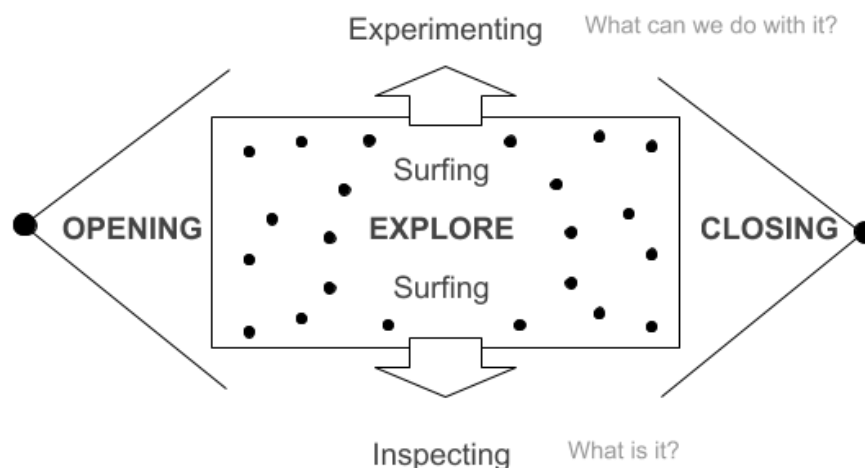
- Try to create the conditions that allow unexpected, surprising and pleasant elements to emerge;
- Proceed without a plan, improvise, and role-play to be placed in the situation.
- Create a space to understand the problem, improvise, look for randomness, change and reformulation: **NAVIGATE / SURF**
 - Use a GAME to NAVIGATE: live in the present, look around and get something, join in, create a game with simpler tools. The game will move you forward. It is not necessary to know what the final destination is, but only the next step of the journey. It will be enough to take into account the fuzzy objective that we created in the previous phase.
 - Link the GAMES (**Braingames**) to NAVIGATE: do not pretend to close before exploring, the next "game" will allow a step forward in the more or less correct direction.
- Make drafts and models: **EXPLORE**

- Look for patterns and analogies, see old items in new ways, sift and classify ideas.
- Try the models: **INSPECT**
 - INSPECT, create models and sketches that meet the following conditions:
 - Informality;
 - Laxity;
 - Brevity: for example, cardboard or plasticine, etc.
 - Tangible and concrete prototypical ideas: a model to test, explore and exploit.

Braingames

Basic game skills (brainstorms¹⁸ / BRAIN-GAMES) for **NAVIGATING**: Brainstorming in various forms.

- Questions: Ask questions!
 - Opening questions;
 - Questions to navigate or explore, inspect and experiment;
 - Questions to close;
- Create components and an understanding **SPACE**: Generate nodes (Post-it).
- Connect the nodes (post-it) by affinity and link diagrams in the **SPACES**.
 - Establish limits and classify (different affinity diagrams):
 - XYZ AXES; CONCENTRIC CIRCLES; QUADRANTS; PROS / CONS; IMPORTANCE; SEQUENCE; IN OUT; TARGETS HOUR; LANDSCAPES AND MAPS; METAPHORS, etc.



All companies make some kind of journey, they go from one place to another and each market is a landscape with its own dangers, challenges and opportunities. These challenges can be used to set the opening questions geared toward focusing ramblings.

- What journey is your company on?
- How do you present the way ahead?
- What way is there to go?

¹⁸ Brainstorms: <https://en.wikipedia.org/wiki/Brainstorming>

- What obstacles are there in the immediate future?
- What is further from the demand?
- What forces drive you to move forward?
- What forces support you?

⇒ EXPLORE (1) ⇒ INSPECT (2) ⇒ EXPERIMENT (3) ⇒

Asking to EXPLORE (1)

Questions that help to see how difficult the problem is and how far the group has come.

- Are you getting what you need?
- Have you achieved everything you hoped for?
- Do you realize that your collaborators still feel connected to the project?
- We are in the good way?
- Have I understood it correctly?
- Has it helped us get where we want to go?
- Is this discussion topic useful?
- Should we postpone this issue for now and put it on the list for later discussion?
- Does the goal we set this morning still make sense? Or should we make some adjustments to what we've learned so far?

In the example that concerns us and with different forms developed in the First Law based on the initial declaration: "Commercial container that allows the impregnation of Roller without dripping". For example, the forms developed in the first phase would have offered alternatives of the type:

- B.- "Container with integrated roller impregnation tray";
- B'.- "Removal of rigid containers";
- B''.- "Container / tray dilutable in paint / water";
- B'''.- "Container with integrated impregnated tray "AND" Removal of the rigid container".
- B''''.- "Self-absorbing impregnation tray"
- B'''''.- "Self-leveling impregnation tray"
- B''''''.- "Container that impregnates the roller as it is inserted and extracted, only what is really necessary"
- B'''''''.- "Extensible or foldable container with tray"

Each of these states, from B to B'''''' generates a starting point that the Second phase will try to specify a little more, expand or mix between them, just like point B''', which mixes various concepts.

It doesn't really matter that point B'''''''' temporarily getting us nowhere. It is possible that later, we can develop the broken idea that we need. Navigating from point "B-a" to point "B-b" involves developing the idea and then Inspecting and Experimenting, which limits the solutions.

Questions for INSPECTION (2):

Observation and analysis are the result of these types of questions. In general, it is good to begin an exploration by inspecting and testing fundamental assumptions.

- What is that?
- What is it made of, or what is its nature?
- How does it work?
- What are its fundamental pieces?
- Can you tell me an example?
- How does that look?
- Can you describe it as if you were in a scene from real life?

Clearly the inspection specifies the ideas. But it is important not to set preconceived limits. In the case of the example, the elimination of the rigid container could also imply not only flexible plastic bags of the BAG type, but we can also navigate to another state B''' from B''.

B''.- Container / tray dilutable in paint / water;

B'''.- Special dispensers or vending machines for personalized paint, in stores, in flexible or rigid or even dilutable containers and trays.

Even in this way, we could conclude that we do not need the rigid container and can continue to use the painter's kit with tray, tray and roller. This last detail would be part of the Inspection.

Questions for EXPERIMENT (3)

Experimental questions spark the imagination. They are related to possibility. What can we do with it? What similarities do you create? ... These experimental questions lead to a higher level of abstraction to find similarities with other things, to make unlikely and unexpected connections.

Experiment: Try breaking it, throwing it, flipping it, flipping it, and doing many more "wild" and unexpected activities.

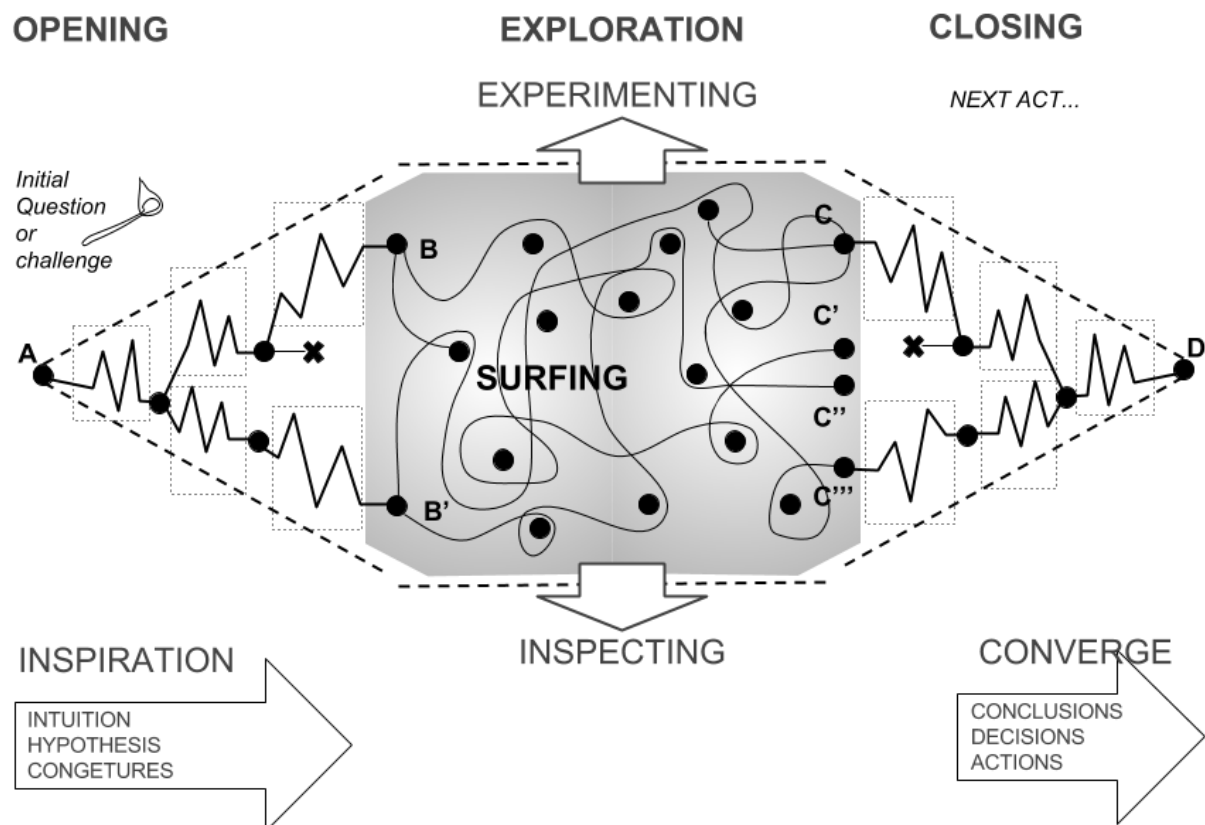
- What can I do about this, beyond the obvious?
- If it were an animal (or a plant or a machine), what kind of animal would it be?
- What are we missing?
- What would happen if all the obstacles disappeared?
- What if we were wrong?
- How would we handle this if we had a restaurant? What if it was a hospital? Or inside a car? Or in the pool? ...etc.

When team members are too involved in details, ignite the imagination and take them to a higher level of abstraction with some experimental questions.

And, if they are in the clouds in the Exploration phases, in this phase they will have to put their feet on the ground and lower them with some Inspection Questions. The questions for Experimenting will change the mind even a certain critical state "C", looking for problems, obstacles, etc. They will take us from B to C ("C" for "Critical").

VII. ACT THREE of the Design-Thinking session:

CLOSURE - CONCRETION - DETAIL - ELIMINATION - IMPLEMENTATION - CONVERGENCE - ACTIONS -
MANUFACTURING - MINIMUM VIABLE PRODUCT - WORK PLAN.



The second phase would take us from the states B..B'''''''' to the already experienced and investigated states C..C''. From these "C - solutions" we must choose, eliminate complex or perhaps ridiculous shapes or dead ends. We intend to delimit the land to select the most promising elements.

The elimination decisions will be taken, generally by majority, although it is advisable to do so by unanimity of the group.

Each country and culture need to move at its own speed. There are cultures that require more time to reflect than others that are more action-oriented.

In closing, the use of Edward de Bono's Six Thinking Hats tool is very useful when evaluating each C state from very different perspectives. Then we will choose from one to three D states, depending on the technique we select to prototype.

Prototype and Working Plan

At this stage, the final state “D” must be specifically specified and even prototyped. The prototype does not have to be real, but can even be a series of drawings. The Minimum Viable Product (MVP¹⁹) figure appears at the end of this session, along with a work plan for the group and subsequent sessions. That is, we end with the definition of a PUZZLE.

The problems detected in the prototype can be the subject of other Design-Thinking sessions, within which solutions to the problems detected in this last phase of prototyping or MVP will be faced.

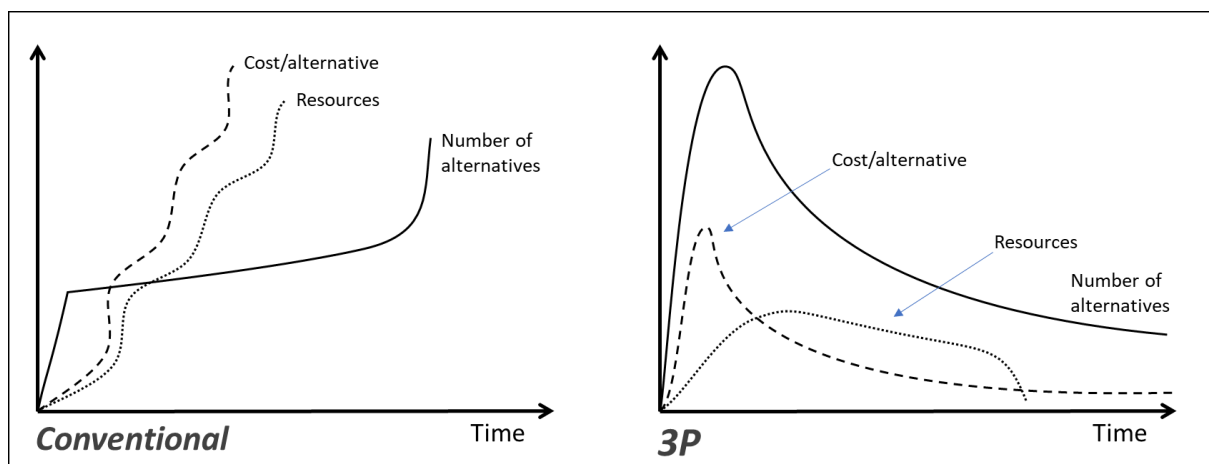
3P and Manufacturability

Once we have one or more ideas screened by the simulated experimentation and inspection process (Passing from states “B” to “C”) of phase 2, it is possible to make semi-functional prototypes in an artisanal way, in order to validate the ideas presented and go from the “C” states to the final and final state “D” where we will have already defined a producible MVP.

To achieve this, the 3P tool provides us with a wide range of processes and tools with a very broad spectrum and focus.

"3P validates the idea or the MVP regarding manufacturability"

The **Production Preparation Process - 3P** is an advanced approach involving visual thinking, simulation, *kaizen* for rapid design of the manufacturing method.



3P follows a series of group and individual activities to outline and model the product and processes. **3P** consists of an intense 3 to 5-day event dedicated to practical idea generation and simulation.

3P is about rapidly designing products and production processes to ensure capacity, built-in quality, productivity, and Flow-Takt-Pull.

¹⁹ MVP: https://en.wikipedia.org/wiki/Minimum_viable_product

3P minimizes necessary resources such as capital, tools, space, inventory, and time. Instead of adjusting an existing process in the workshop, we started with a clean sheet of paper, involving workers on the first line of production in its development, and thereby motivating them to contribute new and groundbreaking ideas or identifying problems that in many cases were they had escaped us in the definition process.

The **3P** process is also used to develop a specific product line production system in the shortest time possible to meet design and quality requirements, concept-to-market time objectives, production requirements, and requirements. cost.

"80% -90% of the operating cost found after construction or design launch is directly related to decisions made during the design phase."

3P simulates the actual components, the product, and the production line of a new product during the early stages of the design process to understand manufacturing or delivery requirements before committing to a process plan or flow.

Without understanding **3P** and how it differs from traditional approaches to product and process design, many 3P projects can be questioned, criticized, and shortened before completion. Because as we hit the plateau with Continual Improvement, we get into a cloud of uncertainty. And, 3P drives us to break this cloud. This is risky. Less than 10% will jump to it. But **3P** will take us to a new level where **Kaizen** will start with a new perspective. And, by doing this, we renew our **Kaizen** enthusiasm with new direction and vigor.

The objective is to satisfy customer demand with perfect quality and at the desired cost.

From start to finish, **3P** is a project management and waste disposal exercise. 3P is a valuable tool because the cost of eliminating waste in the early stages of product development is lower than during the final stages.

The tool is useful and effective when you need to develop a method to meet customer requirements, plan production capacity for new or changing demand, transition new products, set a target date to deliver to market, or test cost. objective of the business case.

In the case of the example in the next chapter, we will try to develop a method for quick part or die change within a SMED workshop. In this example, 3P serves to simulate the method and try to standardize the operations in this prototyping phase, evaluate the possible failure, as it would be done in an FMEA study, but not in an exercise of imagination, but within a work exercise simulated.

The most important work of **3P** is the final documentation, including the simulated standardization using the format that will be seen later: QCPD. In this way we can document the process to improve in the following interactions during the implementation of the developed process and especially in the following occasions that we develop a **3P** workshop

3P session team

3P's cross-functional team should include designers, engineers (i.e. manufacturing, quality, and processes), operators, operations experts, and any other key people to bring the product to market.

Using “Lean” principles, the cross-functional team creates a product mock-up and explains how the product will flow through the factory. The mock-ups can be made out of cardboard, plastic foam, wood, or whatever other material makes sense. Typically, multiple 3P events are required during the design and development phases of a new product.



“3P must be actively practiced and promoted. If 3P's efforts do not continue to advance, they will regress. Along with this regression go the competitive advantages and the money invested in discovering, creating and implementing the process”.

3P STEPS simplified

1. Determine the role: What role does our customer want?
2. Collect Real Data;
3. Develop 7 alternatives (7 ways): Don't just jump to "the idea"!²⁰
4. Look for examples in nature;
5. Prototyping Area: Build something with your hands!
6. Evaluate 7 alternatives;
7. Select 3 best alternatives using objective criteria. Rating 1-5 each consideration for the 7 alternatives;
8. Build operation models: Tray-Storming;
9. Simulate 3 process alternatives;
10. Select the best combination of design and process;
11. Create standard job and control;
12. Develop team concepts: define, draw and;
13. Develop an implementation plan;
14. Follow up!

Is it a redundant effort to generate 7 alternatives and choose the best 3, when we have already developed many alternative ideas in phase 2 of our Design-Thinking process? ... The **3P** Process focuses on real processes, not on disruptive design or innovation in new products. These problems

²⁰ Develop 7 alternatives: Can we apply Design-thinking? ... of course, why not? ...

can condition the design to better adapt to reality, to the available technology, to the productive economy and ultimately to the Factory management or Management System.

But yes, the initial 3P approach is redundant with the Design-Thinking approach described in this reading. In many cases, the Design-Thinking session can be integrated into the seven first steps of the 3P tool if ground-breaking innovation is considered in production processes.

Detailed steps in a 3P session

1. Determine the role: What role does our customer want?
Understand customer requirements: PESTEL, STEP, Empathy-Map, Surveys, etc.
We must focus on defining the requirements to produce our designed element: Number of units, Customers, Seasonality, Capacity and Quality, Technologies, Equipment capacity.
2. Collect real data:
 - a. What simulation data can be collected to rate how each model can work?
 - b. Go to Gemba: Understand the current state.
 - c. Follow the Paths: How does our customer use our product?
3. Develop 7 alternatives (7 ways): Don't just jump at the idea!
 - a. Each alternative must be a viable solution
 - b. Define: What would be needed? For the idea to work.
 - c. Don't evaluate ideas, focus on what might work.
 - d. Consider the process steps, not the equipment.
and. Don't trust old or internal processes. Select what is best.
4. Examples in nature.
 - a. For example, the VELCRO. What is done in nature in a similar way?
 - b. Find out how nature works.
 - c. Background and conditions of the function: How does nature interact with the environment? Make a sketch!
5. Prototype: Build something with your hands!
 - a. A method of disruptive action that occurs in secret, around the organization limits & procedures, producing an improvement of order of magnitude for any process.
 - b. A lean manufacturing tool that uses a fast and inexpensive prototype to develop and test a concept, before full implementation. (Similar to the minimum viable product-MVP). Fast and inexpensive is the only way to "Tray-Storm"
6. Evaluate 7 alternatives.
 - a. Simulate product functions.
 - b. Simulate process functions.
 - c. Create an alternative process at a glance like in a Comic.
7. Select 3 best alternatives using objective criteria: Grades 1-5.
 - a. Takt Time.
 - b. OPF: One-Piece-Flow.
 - c. Participation of all workers.
 - d. **Hanedashi**: Automatic ejection devices.
 - e. **Chaku-Chaku**: Automatic parts loading and unloading based on the simple force of gravity.
 - f. **Poka-Yoke**: Inadvertent mistake.
 - g. 100% commitment.
 - h. Value added.
 - i. SMED / Quick change

- j. Maintenance of the tool room.
- k. Tool costs.
- l. Ergonomics.
- m. As simple as possible.
- n. Standard equipment.
- o. Process capacity - Cpk
- p. Already Known process.
- q. Future challenge.
- r. Maintenance free or easy maintenance.
- s. Technical advantage.
- t. **Jidoka**.
- u. Minimum investment capital, Time of development.
- v. Analysis and relevance of the customer's point of view
 - i. Interest "1" in the customer's point of view
 - ii. Interest "n" in the customer's point of view
- 8. Build operation models: **TrayStorming**.
 - a. **Ishikawa** diagram of each part and / or process: clarify the steps and parts of the product and process: Clear and visible process map on a wall in a linear way.
 - b. Spaghetti diagram and / or chain model.
 - c. Map of potential problems: Mind-Mapping by Brainstorm.
 - d. Simulation and modeling: post-it note, Lego, large panels, floor, ribbons.
 - e. Live models
 - i. Eliminate the assumptions of 2D media.
 - ii. Improves creativity, teamwork.
 - iii. Fast and inexpensive.
 - iv. Brainstorming "vs" Tray Storm.
- 9. Simulate 3 process alternatives.
 - a. Test inefficiencies in live mock-ups.
- 10. Select the best combination of design and process.
 - a. Does the design meet the objectives?
- 11. Create standard job: QCPD (See the SMED-Worshop).
- 12. Develop team concepts: define, draw and model to:
 - a. Tools, instruments and equipment.
 - i. Lightning speed (Maximum speed).
 - ii. Material flows and **Jidoka**.
 - iii. Absolute minimum.
 - iv. Easy equipment changes and SMED.
 - v. Easy to move equipment.
 - vi. Narrow operator stations and U cells.
 - vii. Work flow.
 - viii. No loss of team time.
 - ix. Small fast flow lines.
 - x. Short vertical lines.
 - xi. Pull-Production.
 - xii. Quick tool changes: 10 seconds in the factory / 15-20 seconds in the office.
 - xiii. Machines or devices for linking cells or lines.
 - xiv. Multiple rectified lines and flows.
 - xv. Do it again!
- 13. Develop an implementation plan.
 - a. GANT and KPIs.
- 14. Follow up!
 - a. PDCA... Check-KPIs & Act... Check-KPSs & Act... Check-KPIs & Act... etc.

VIII. *SMED-Workshop under Design-Thinking*

In this example we will develop an example of a Design-Thinking session in the definition of an industrial process and its corresponding improvement by means of the SMED technique. By using SMED we have already defined a possible **initial state "A"** based on the target time limit in the realization or stoppage of the machine considered for carrying out the part change activity.

Single Minute Exchange Die or SMED²¹ allows production changes to be executed quickly by reducing batch sizes and speeding up production. It is based on outsource or externalize the preparation of the machinery (supports, dies, ties, etc.) and the optimization and parallelization of internal and external preparation tasks so that we can reduce machine downtime to less than 10 minutes: Presses and their dies, etc.

This concept was developed by TOYOTA in the 1960s and 1970s to accommodate highly variable production, thus reducing optimal production batches at greatly reduced costs.

In fact, SMED and POKA-YOKE²² are the fundamental concepts for the development of quality in production developed by Toyota and Shingeo Shingo and, complementary to the TQM developed by Kaoru Ishikawa and the House of the Toyota Production System²³ developed by Taiichi Ohno.

The team tackling this challenge can be made up of workers across the spectrum, from front-line workers to engineers, supervisors, and office staff, so that diversity is wide. And, diversity is precisely the key to success.

It is important that the group and its leaders know that the approach to the 10-minute goal for quick change is a progressive approach. Thus, several processes may be resolved in one session; Outsourcing and grouping many of them, but the SMED goal will require a continuous effort by several work sessions. And, changes may even be achieved even faster than the 10-minute goal. For example, in Toyota there are die changes in the presses, which in the 70s were already done in 10 minutes, but now they are done in less than 20 seconds of machine stoppage.

Commercial solutions or Design-Thinking?

To achieve this reduction objective, for example from, for example, 90 minutes to 9 minutes, many times the team facing this challenge has to imagine novel solutions, and think “outside the box”. But... You could not, yes, and just look for commercial solutions. However, trying will always lead to new knowledge that sooner or later will revert to the improvement of this or another process and above all trains the mind to see all the problems of the solution posed from all points of view, avoiding errors in the conception of process engineering projects.

After all, the production engineer must evaluate all the possibilities at his disposal and not restrict his activity to that of “catalog engineer”, with its consequent mental restrictions. The job of an engineer

²¹ **SMED:** “... Is a method of reducing waste in a production system that is based on ensuring a tool change time of a single digit of minutes.” https://en.wikipedia.org/wiki/Single-minute_exchange_of_die

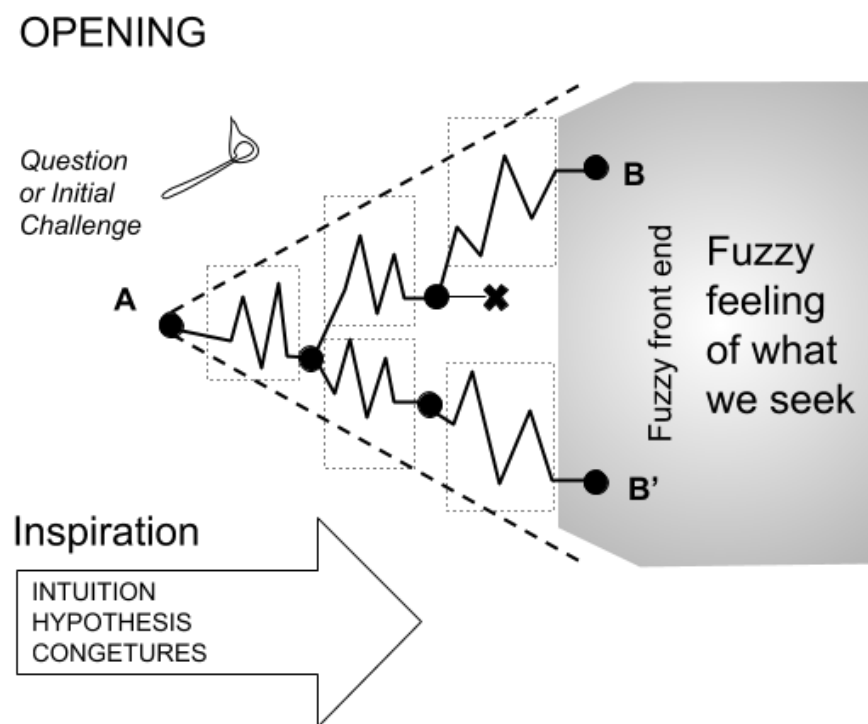
²² **Poka-Yoke:** “...es una técnica de calidad que se aplica con el fin de evitar errores en la operación de un sistema” <https://es.wikipedia.org/wiki/Poka-yoke>

²³ TPS: https://es.wikipedia.org/wiki/Sistema_de_producci%C3%B3n_Toyota

is, therefore, to design the process and within it, choose or even design and, where appropriate, order the best tools and means to carry it out. The errors of not **designing the process** and limiting itself to ordering a solution are very wide in the industry and, their consequences are very costly, discouraging and demotivating, especially for the workforce that executes them on the first line of production.

In the case of a SMED workshop, such as the one considered, the perspective based on the Design-Thinking methodology will obtain ideas which immediate development couldn't be carried out in the short term. But, without a doubt, all these ideas, which could be ridiculous or crazy initially, could lead to new developments on roads that otherwise would not have emerged.

Preparation and definition of state "A"



It is a fact that in the industry you work with real situations and in a certain way you should work with the scientific method, based on data, not on intuitions.

And, although many times it works like this, it is also true that intuitive thinking is predominant in the industry many times. This is when you work with assumed or budgeted data, biased views or intuitions. It is important to obtain the real and current data and as **Sensei** Koichi Kimura says: "*The data and the Sashimi the fresher the better*".

The definition of point "A" is, in this case, critical and must be done through a thorough study of the current circumstances surrounding the process. An up-to-date and deeply detailed process map is the best option to define the "A" state.

And, to know deeply and understand the problem to face there are many techniques. One of them is used by Toyota and is called "Data collection sheet to solve a problem". It clarifies what we know and what we do not know, suppose or need to know or need to imagine.

Problem Solving Data Collection Sheet		
Differentiating facts from assumptions		
#	What I do know and How do I know about the problem	What I need to find out about the problem
1	Facts we can document...	Assumption we cannot document for now: If we have to make an assumption at the moment that we document it, and then we return for more data!
2	...	...

In many cases, especially inexperienced engineers, assumptions are often assumed to actual facts. Thus, in order to prevent this behavior, Sensei Taiichi Ohno usually traced one circle on the floor and he said to the novel engineers *“Please, stay into this circle till you understand deeply what is the process you are looking at”*

That is, many managers and engineers usually assume that things happen as they want them to be or should be or happen according to them. But, without a face-to-face, detailed and exhaustive verification of the true process, the definition of point "A" or the actual process studied could be deficient. And then, the conclusions were deficient.

A work Agenda of the Design-Thinking session

The definition of state "A" is an objective work and that may be carried out in the days or weeks prior to the Design-Thinking session or sessions and should be specified and presented to the group for their consensus on the day of the initial session of the First Act . However, the need to change the mind from an objective and critical state to a subjective and imaginative one in order to develop Design-Thinking sessions requires several days of training.

In my experience, a Design-Thinking workshop from Wednesday to Tuesday with four days of continuous work, and a weekend in between, is the most creative solution and allows us to adequately deepen the matter. It also allows you to confirm during the first days of the first week: (Monday and Tuesday) that the “A” status is properly defined.

From Wednesday to Friday of the first week the group works on the first and second acts. The third act takes place between Monday and Tuesday, leaving the rest of the week for documentation work or the “soft” prototyping session under the 3P methodology.

In many cases the session can conclude in 3 or 4 days, although in cases that include prototyping under 3P methodology, this duration may be short. In these cases, it could take another day or two. However, this creates unnecessary stress on normal industrial processes. Returning to the normal work of each team member is also a priority in the factories. The special isolation, continuity and teamwork that Design-Thinking sessions require is incompatible with day-to-day work in a factory.

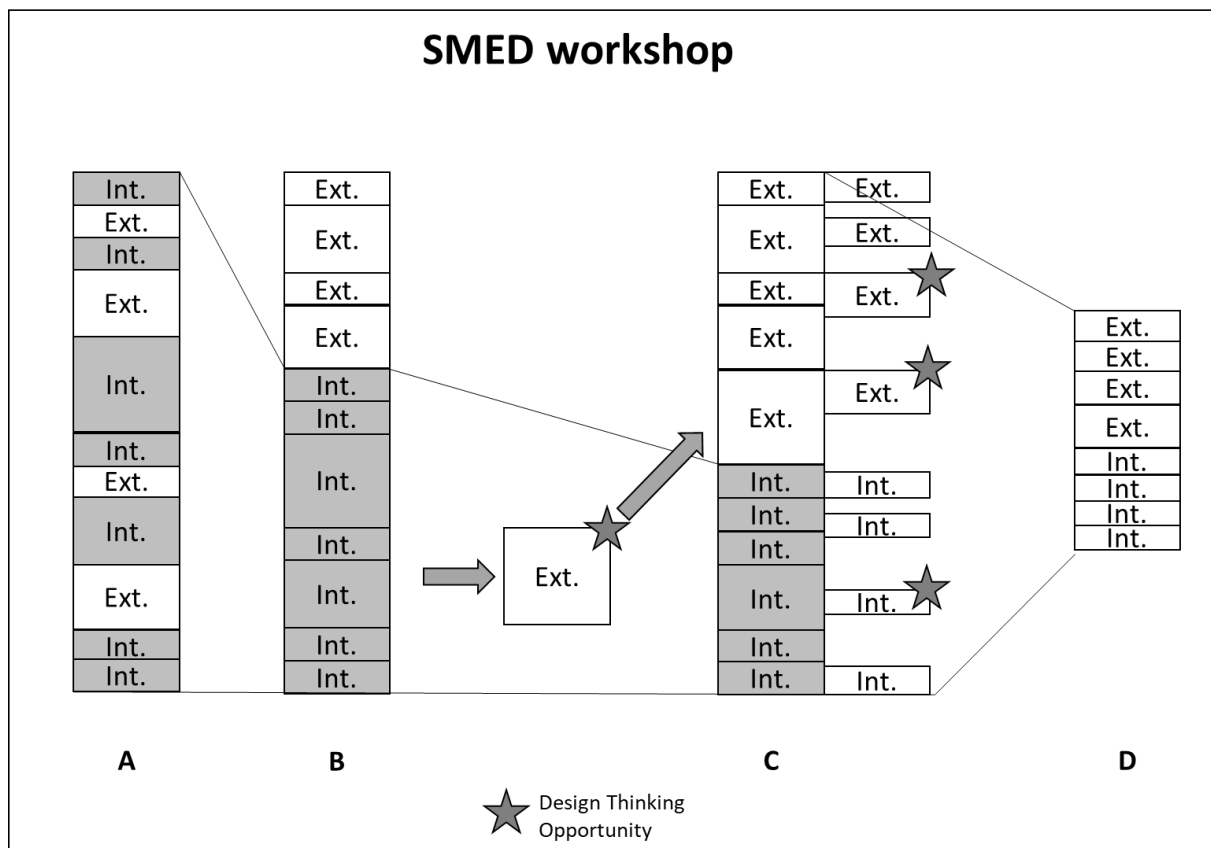
In this regard, Design-Thinking sessions are closely related to the **Jishu-Ken** sessions of Japanese origin, in which a group faces a problem until its final resolution, without time limit. Although **Jishu-Ken** sessions tend to be more rational, based exclusively on recent data and their duration does not usually exceed the working day, no matter how long it may be. Thus, on the first day (Wednesday - X) of the session, state "A" should be completely defined by mapping the process.

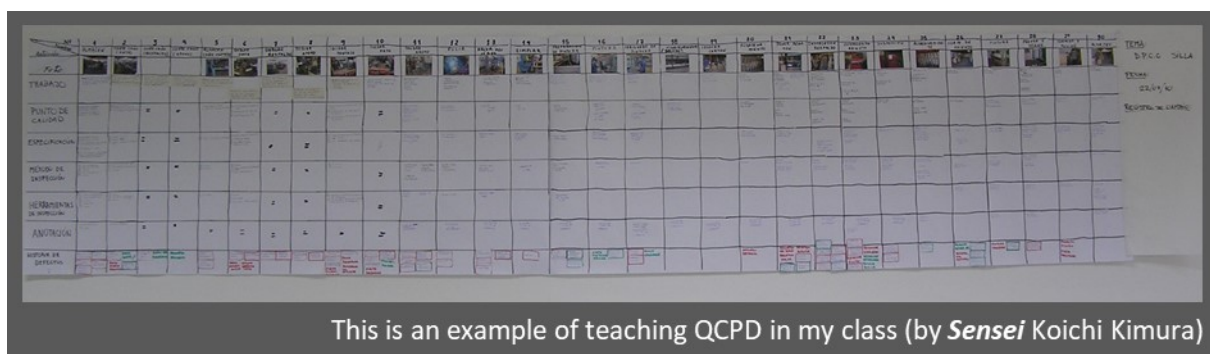
Industrial process <i>Design-Thinking</i> workshop agenda											
Week 1						Week 2					
L	M	X	J	V	S	D	L	M	X	J	V
..Process-Map	..Process-Map	ACT ONE	ACT TWO	ACT THREE			ACT THREE	ACT THREE	3P	Doc.	...

In the following graphic you can see a general example of a mapping of an adjustment process in any machinery. Operations that are carried out internally and paralyze the machinery that we need to keep running are indicated with "**Int.**". And, the operations that do not paralyze the machinery to the line and are carried out externally are indicated with "**Ext.**".

The opportunities to develop a Design-Thinking workshop are shown in the preceding graphic. For example, the externalization of certain operations that are carried out internally in the machinery or in this case in the milling machine. In this outsourcing process, groundbreaking ideas can be developed, as well as in the grouping and elimination of some external tasks.

Both phase A and phase B can be taken as point "**A**" for our *Design-thinking* workshop. However, the best option is to have grouped and ordered the internal and external tasks in phase B, prior to our session. Because this work is a rational task of analysis and repositioning of tools, machinery and tasks, but it does not require spatial thinking "outside the box", but rather a deep deployment of the **5S** methodology and Process Standardization.



This is an example of teaching QCPD in my class (by *Sensei* Koichi Kimura)

PROCESS QUALITY CONTROL DIAGRAM – PQCD							DATE: ____/____/____
Team				Product:		Actual Page Total Pages	
1				Version No:			
2							
3				Comments:			
4							
5							
6							
Proces No:	1	2	3	4	5	6	7
ISSUE:							
PROCESS PICTURE							
DETAILED JOB							
POINT OF QUALITY							
SPECIFICATION							
INSPECTION METHOD							
INSPECTION TOOL							
ANNOTATION							

Standardization of processes for the definition of point "A" in Design-thinking

To carry out the standardization of the processes, the initial and the most important step is the mapping using the format set out below previously: “**Data collection sheet to solve a problem**”. And then, the process is carried out in detail by means of the “**Quality Control Process Diagram**” or **QCPD**.

With this format, the collaboration of front-line workers can be achieved in its definition and verification, by exposing the process on a wall in a linear manner, even occupying several meters of wall.

Deeply documented standardization is not necessary, in this case, precisely because we are changing the process. However, we do have to know it in depth and, this **Quality Control Process Diagram** is the easiest and most collaborative means available.

The standardization sessions must be carried out in collaboration with the front-line workers and by hand, never using the computer or computerized editing in the first phase. They can then be transferred to an edited digital format for the integration of the photographs and the debugging of possible errors in manual data collection.

5S+4R

Once we have clearly and in detail defined the process, we must develop the 5S²⁴ tool in a **deeper** way. Standardization allows us to determine what is really necessary and what is not, when and how it is necessary, and to establish the Rules or standards of execution of the 5S maintenance-level process (**4R: Create the rule, Teach the rule, Keep the Rule and Update the rule**)

And once we have deployed 5S after standardization of the processes, we again take updated times under this new condition and update the DPCC. After that, we will realize that we have already started saving time. To take the times per operation and the total, we can take the best of 10, as is usually done in Japanese industry, always with the highest level of skill available among regular workers. Never the average, since it is not a goal for the rest of the workers and discourages maintenance, improving times under the standard and improving skills.

For practical purposes, this exercise of "Standardization + Deep-5S" usually has a minimum impact of approximately 25-35% on time savings in internal and external tasks. Which represents a considerable savings, even before actually starting the SMED workshop.

Really the deep deployment of 5S + 4R is the first step, according to **Sensei** Koichi Kimura for the development of the SMED tool. Although from a Western perspective, this first and necessary initial step of standardization (4R) of 5S operations is usually ignored.

Definition of a in the initial state "A", of a milling machine

After studying the process **deeply**, we choose a part of it that we intend to externalize, group and accelerate, to free up productive time on our machine.

Let's imagine, as is usual in a milling machine, that the greatest downtime of the machine corresponds to clamping and measuring the part to be machined. This work actually occurs, even several times in the same piece, depending on the morphology of the piece and the machinery available.

At the beginning of this work on defining point "A" we are not going to evaluate the possible technological alternatives available, even if they are present in the team's thinking. Team have to establish the initial question from point "A" without establishing preconditions based on correct or incorrect assumptions.

²⁴ **Sensei Koichi Kimura Lectures about 5S**

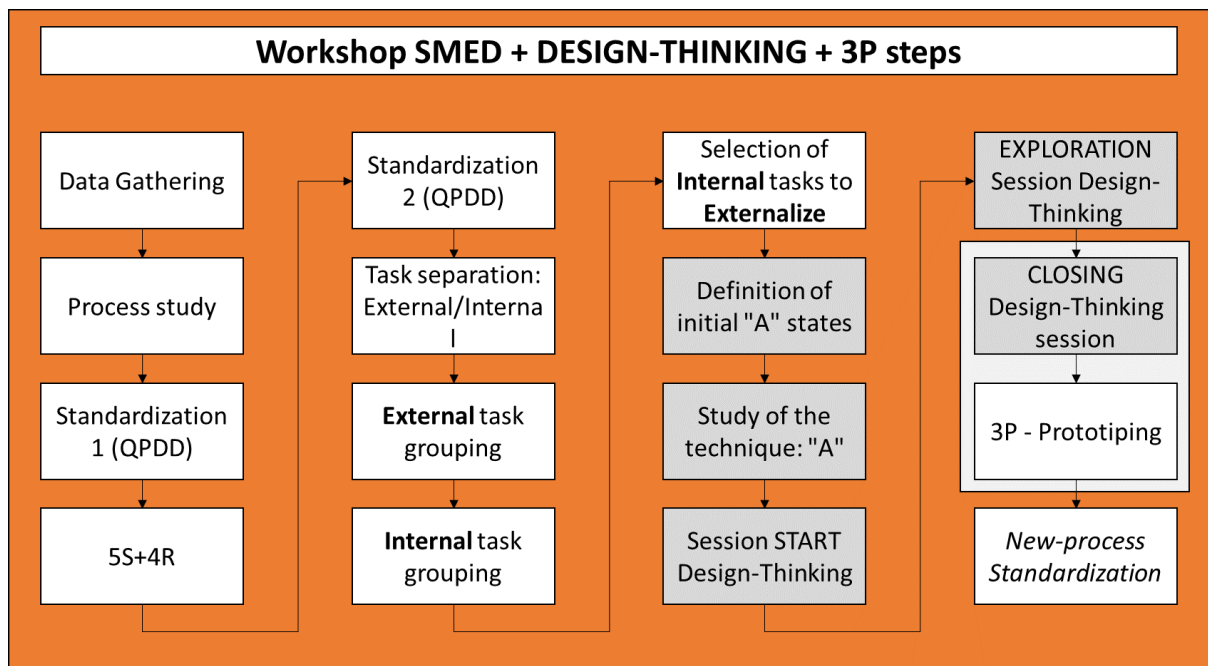
Spanish 5S-1: <https://archive.org/details/5s1spa>

Spanish 5S-2: <https://archive.org/details/5s2spa>

English: 5S-1: <https://archive.org/details/5s1eng>

English 5S-2: <https://archive.org/details/5s2eng>

5S Wikipedia: <https://es.wikipedia.org/wiki/5S>



This possible study on the available technologies would limit the solutions and create restrictions that we precisely try to eliminate with this *Design-Thinking* methodology. In fact, if we were to go directly to evaluate commercial alternatives, we would return to the traditional approach that any “Catalog Engineer” carries out in their daily activity.

Study of the technologies available for clamping the part to be machined.

I must admit that I personally did that study while preparing this reading and I found numerous elements available, such as LASER-3D scanners, probe arms or LASER to carry out measurements external to the machinery.

However, every available solution limited my thinking. That is, it went directly to the second act and to the "Inspection" phase, ignoring the "Navigation" and "Exploration" phases. I realized that I was losing many development possibilities based on the potential of the Design-thinking methodology and above all cheaper, although perhaps also more rigid.

The work of the engineer changes when exploring solutions that perhaps at a given moment may seem ridiculous and, nevertheless, the path led me to discover surprising methods, despite the fact that I developed the Design-thinking exercise alone and in small free moments in the production plant, so the solutions proposed may not be as imaginative as they could have been in a group and diverse environment.

In this example workshop, each part change represents between 1½ and 2½ hours of machine stoppage (we consider 2 hours on average), with one change for each work day. In this way, the SMED workshop is of vital relevance to increase the rate of processed parts and improve the OEE in an approximate way $(2 \times 100) / 8 \text{ h per shift} = 25\%$.

Suppose also that the piece, once built by welding work, has tolerances of less than 5mm. This may seem like a great tolerance, however, this data limits and helps to determine the possible solutions to be designed. We also suppose that the part may be similar to the one shown in Figure 1, although

we do not need this data yet. And also, suppose the milling machine is a 3-axis XYZ machine, like the one in the image in Figure 2.



Figure 1: Sample Piece. Source <http://www.egondo.com/producto/caldereria-pesada/>

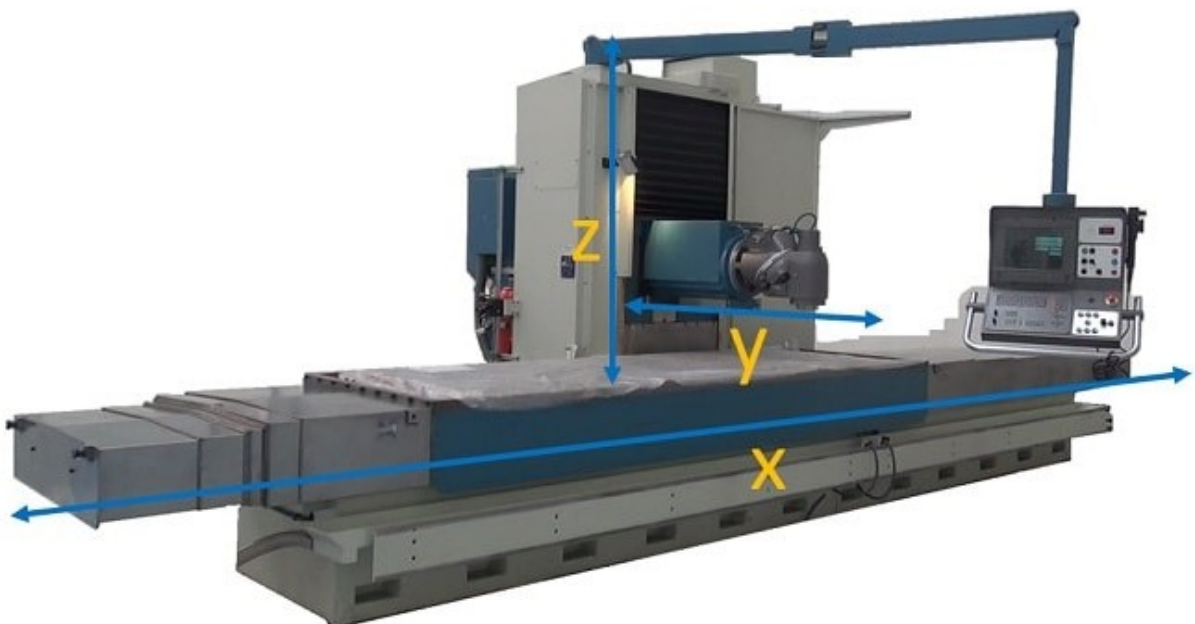


Figure 2: Source: <https://www.ncservice.com/es/como-funciona-una-fresadora-cnc>

Thus, we have defined the state or some states "A" or, internal processes to improve (**Int.**) And the processes to externalize (**Ext.**). Under the following definitions and, based on the processes previously studied and grouped between internal processes that we want externalize and accelerate in this SMED workshop.

States "A":

Int.A1. - Quick external measurement of a piece of about 2x1x1m to be machined in more than two positions and, built with tolerances of less than 5mm outside the machine. We need to define its ZERO point and subsequent critical or reference points that this machining program needs. (**Int.A1 → Ext.A1**)

Int.A2. - Quick external clamping of the 2x1x1 m piece (**Int.A2 → Ext.A2**) for its machining and the means of quick positioning in the work area of the machine tool.

Int.A3.- Evacuation + Evacuation + Placement: Evaluation of the quality of the machining of the piece and its Evacuation of the work area and, finally, placement of the new one already clamped/fastened and measured by Ext.A1 & Ext.A2.

The time limitation is in the **Int.A3** process: **Evaluation + Evacuation + Entry:** Less than 10 minutes because the rest of the processes should be outsourced (**Ext.A1** and **Ext.A2**). Although it could be done step by step as processes are outsourced and grouped outside the machine. Thus, we have the technological and engineering challenge in the outsourcing of the **Int.A1 → Ext.A1** (Measurement) and **Int.A2 → Ext.A2** (Mooring) processes.

We do not consider other accessory processes for the moment. Each problem requires a specific session. Nor do we consider the process globally, mainly because we try to apply a maxim in the optimization of processes based on the premises of **minimum investment and maximum performance**.

Thus, each work session can be limited to solving a single, specific and detailed problem. However, if we were a company that develops this kind of solutions or machines, we should consider the problem as a whole and thus develop a ground-breaking solution in the Design-Thinking session.

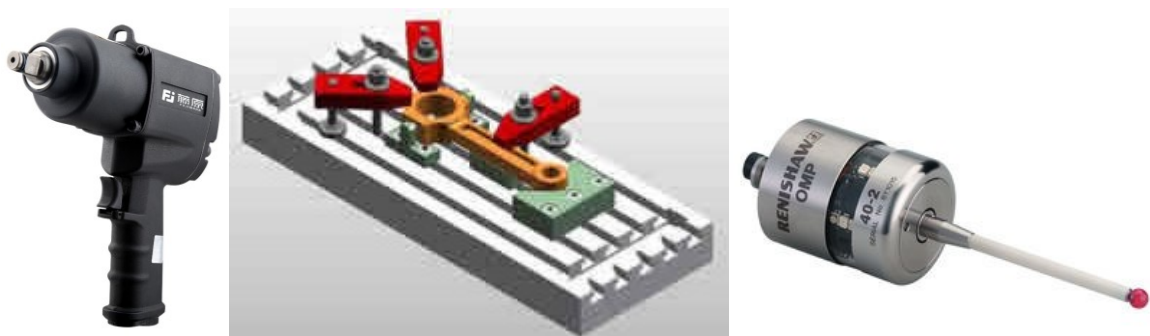
These three "A" states represent a special challenge because normally SMED, was developed for die change in presses or, in this case, it would be applied in a traditional way to part changing. But in this case, we want to externalize something that is not usually done, which is the measurement of the piece. This work is usually done on the machine and represents significant downtime in the production cycle of some parts. We might even have to reconsider externalization of the measurement processes because the available technology does not become efficient or accessible, just yet.

Process Data

In the case we have studied, the measurement time represents approximately 10-15% of the total time of the part on the machine. And as for the fastening and placement of the piece, this time is approximately another 10-15% of the total time. Thus, both processes represent between 20% and 30% of the total machine downtime.

The minimum time used for the placement, measurement, evaluation and evacuation of the piece is now one and a half hours (90 minutes) and the maximum of 3 hours (180 minutes). We have to spend, therefore, from a minimum of 90 minutes to a maximum of 10 minutes, machine stop.

In the study of the process we describe that currently the clamping of the part is carried out by means of tightening bolts by means of a pneumatic impact gun (Left Image), supports specially designed for the part (Center Image) and the inlet and outlet are It is now carried out by means of an overhead crane and the measurement is carried out directly by means of a probe on the head of the machining machine (Right Image).



The above data may not tell you anything if you are not used to working with these elements. But they are some of the many data that must have been collected in the previous phases and during the study of the process. Thus, the SMED workshop team deeply understands the problem to be solved and the true dimension of the time we intend to save.

The Traditional Thinking Model of the Manufacturing Engineering Department

Once the initial states or challenges "A" have been defined, we could go directly to looking for available technological solutions. However, this would limit the solutions, without developing the full potential of Design-Thinking.

That point of view represents the traditional thinking model. Although in many cases the exhaustive and detailed mapping of the processes is not carried out in depth, so the definition of the initial state "A" is based on assumptions or partial information. And the subsequent results are not as expected. The exhaustive mapping of the processes through the DPCC previously exposed is basic for the definition of the initial state "A" and the identification of new opportunities in this SMED workshop.

Once the initial states "A" have been defined, we can now study the technology and available solutions. For example, in this article published in 2016 in Spanish by Interempresas.net²⁵, we can

²⁵ **Grandes mecanizados:** nuevas tecnologías de fijación y posicionamiento:

<https://www.interempresas.net/MetalMecanica/Articulos/158132-Grandes-mecanizados-nuevas-tecnologias-de-fijacion-y-posicionamiento.html>

observe a state of the art that is highly developed and some challenges. It talks about “zero point” mooring systems, although they only solve part of the problem, as we will see later:

“‘Likewise,’ zero point ‘fixing systems are characterized by the rapidity of changing tools or parts, thus reducing change times and avoiding machine downtime. By means of this system a repeatability of +/- 0.005 mm is obtained, offering a clamping force of 60,000 N, which makes it suitable for 5-axis machining where operations with large overhangs are common. In addition, it is applicable in different types of processes and machines”

I. Cerrillo, A. Rodríguez y G. Urbikain, Universidad of País Vasco (UPV/EHU); S. Bretones, de INTI-Tucumán; & D. Martínez Krahmer, from INTI-Mechanics.

This 2016 article is transcribed in Annex A of this reading and also translated into English.

We could stop here and order these solutions from the supplier companies, without going any further. It is totally doable and is the end of many SMED workshops. Although we would lose many ideas that this SMED workshop based on *Design-Thinking* could develop.

The study of the technologies available a priori, may seem to hinder the development of the *Design-Thinking* workshop, because the group may lose the diffuse image of what is sought. The group could focus exclusively on available technologies. However, the group must use this data to create new uses and tools of current technology, grouping, changing or mixing these technologies to achieve the objective of SMED and also consider all aspects of the use of that technology and the problems involved. deal.

The *Design-Thinking* workshop is held to imagine what may seem unimaginable a priori. Thinking of solutions that may seem ridiculous or simply unworkable, but that somehow may also be achievable.

Fuzzy front-end of what we are searching

The difficulty of this SMED workshop under *Design-Thinking* is to maintain the fuzzy image of what you want to develop throughout the process of the first act, when we already know that there are technologies that could solve the problem.

Expert opinion is important in this regard, but it can also limit the various development possibilities too early because these are often too easily self-limited. However, knowing the technologies will make us evaluate the possibilities that go beyond the available technology and what we do not know is, precisely, the potential of the group. This group may have a potential much higher than the technologies initially evaluated and, above all, much cheaper and accessible.

In the example described before and describing a new product development, it is easy to maintain a fuzzy picture of what you are looking for. But now, it is certainly difficult and in many cases the session has to be canceled because the group is heading towards the realization ahead of time, without exploring other possibilities.

https://www.researchgate.net/publication/305658204_Nuevas_tecnologias_de_fijacion_y_posicionamiento_El_mecanizado_de_grandes_piezas_en_Argentina

In these cases, the session should be postponed and the group should reconsider the method of thinking, opening the mind and postponing the work for one or two days, to return to that diffuse image that broadens the range of possible solutions.

Thus, the *Design-Thinking* exercise can be used to develop new avenues of technological research on concepts not considered by the group, during the initial study of the state of the art.

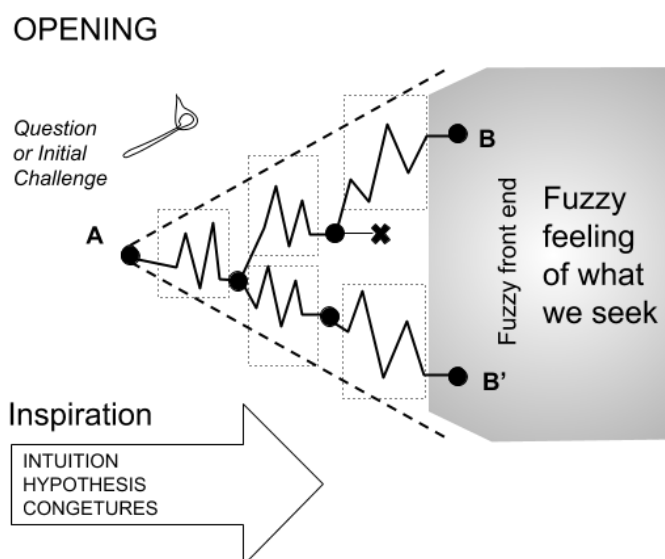
This *Design-Thinking* workshop even serves to organize the ideas of the engineering group that develops this type of work, considering each and every one of the internal and external aspects that can affect the development of industrial processes at the current time or in an immediate future. This is precisely the case that we will deal with here. In this way, we do not intend to develop a ground-breaking solution, but to consider all the possible alternatives that actually exist or may exist.

Practice makes the expert and the fact of considering several possible initial states "A" will allow us to exercise the *Design-Thinking* sessions on several occasions. The second session will lead to better results than the first and so on. Likewise, each state "A" will make us rethink the states "A" previously studied and improve the solutions designed.

Please do not despair if the first session does not get the results you expect and persevere in the practice because all the experts in this technique agree on the need to practice to truly understand how *Design-Thinking* works.

Act One

OPENING - INSPIRATION - IDEAS - INFORMATION - FUN - LISTENING - DEEP DIVING



Defining the "B" states requires imagination and a certain madness, as we have seen in the previous example for the development of the B points in the paint application system.

Thus, we start with an idea that may initially seem ridiculous ... such as: "We can glue the piece to the support to advance in the A1-Clamping of the piece state". This idea will lead us to other possibly

ridiculous and dead-end ideas, but some of them may have a feasible exit today, tomorrow or in a few months.

“Brain-game” in Ext-A1 state: External measurement of the part

We assume that the **Int.A3** state has defined a rapid evacuation system (IN/OUT) which allows us to define and measure the part and its different machining points with respect to a zero-point “on its zero-point support”. This opens up the range of solutions and would allow us to automate the measurement, depending on our budget and cadence.

- B-1) MANUAL
- B-2) AUTOMATIC

We will detail the affinity diagram that we created to define these possible “B” states later with some practical examples. However, the group should develop their own on their own ideas, to get the best results on the basic ideas. In this example, it has been chosen to separate the ideas between Manual and Automatic systems, before going deeper. We simply need a base on which to develop new “B” states later.

These “B” states are diffuse enough to launch a deeper exploration in the next phase.

“Brain-game” in Ext-A2 state: Quick external clamping of the piece

On a clear wall we started our special affinity diagram with the group's comings. Thus, in the example we can start from a Post-it © with the idea USE GLUE. Another Post-it © with the idea of adhering the piece with MAGNETS to another with FLEXIBLE elements such as plastic ties or slings. Another with the idea of holding the piece with QUICK CLAMPING, etc.

- B-1) GLUE
- B-2) MAGNETS
- B-3) QUICK CLAMPS
- B-4) BOLTS
- B-5) FLEXIBLE SUPPORT
- B-6) PNEUMATIC / HYDRAULIC SUPPORT

Each **B-n** state may be developed by the group because even the most ridiculous expressions can lead to brilliant or at least surprising ideas.

“Brain-game” in Int-A3 state: Part I/O, removal and quick placement

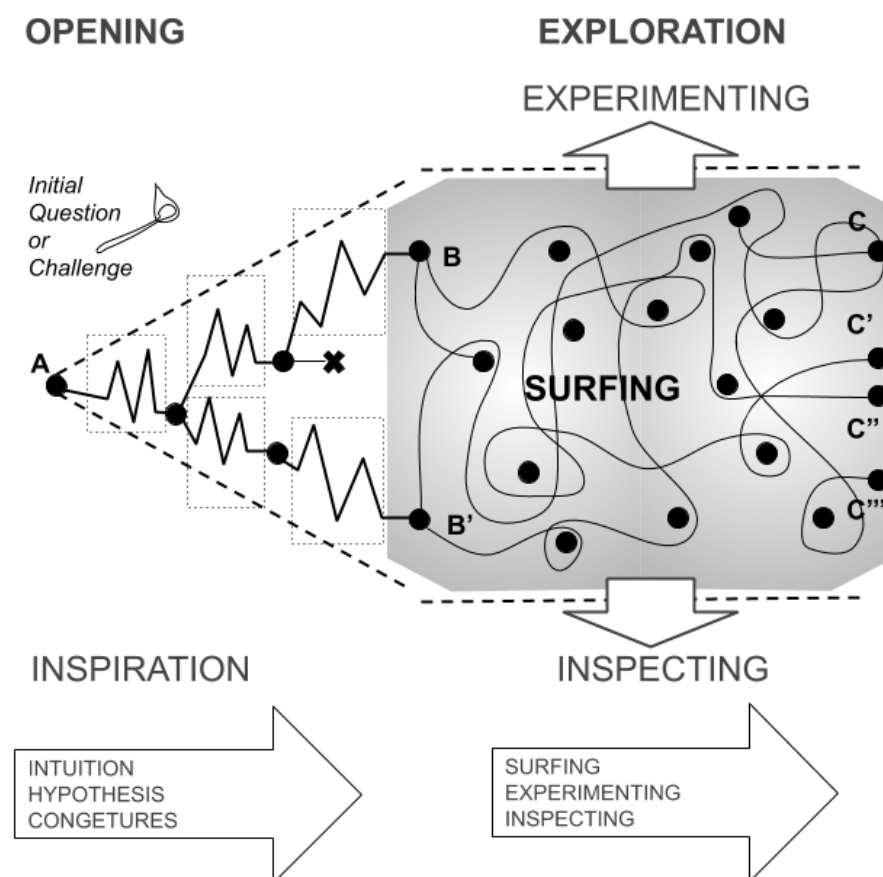
- B-1) DRONE
- B-2) GANTRY-CRANE
- B-3) RAIL
- B-4) FORKLIFT
- B-5) WEIGHLESS MANIPULADOR
- B-6) ROBOT

Each of these states develops, also like the previous example and despite the fact that some may initially seem ridiculous, it may lead us to investigate intermediate solutions or a mixture of all of them that otherwise might not have arisen.

The order in which these different initial "A" states develop is not important. We can start with **Int.A3** or even **Ext.A2** and go back to working on **Ext.A1** at any time. Each of the *Design-Thinking* sessions will teach us something about how to deepen and explore each of them.

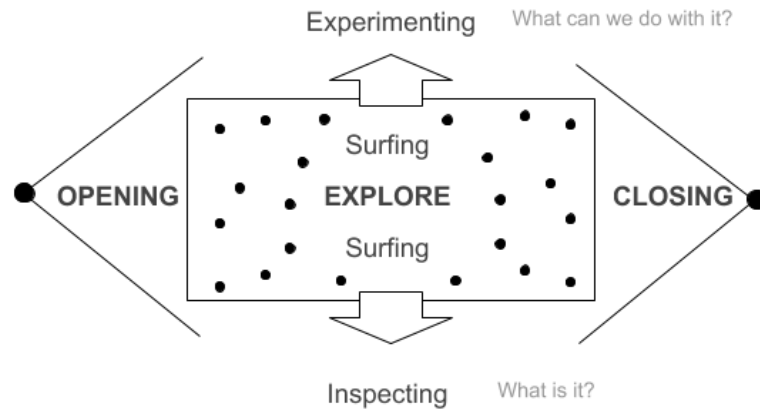
Act Two

IDEATION - CREATION - EXPLORATION - EXPERIMENTATION - INSPECTION.



In this phase we can develop and different deeper "B" states in the NAVIGATION phase, which consists of wandering and getting lost in possible solutions, no matter how ridiculous they may seem now, like some of the ones set out below.

Process Ext.A1: Externalized Part Measurement.



Navigation / Exploration Ext.A1.- External measurement of the piece.

B-1) MANUAL.

- a. References on a traditional template and tool.
- b. Laser tools with reference to a point on the part or template.
- c. Template to see the measurement immediately.
- d. Manual arm with probe, with sufficient precision for the application.
- b. Scanner-3D Manual

B-2) AUTOMATIC.

- a. Anthropomorphic robot and a probe with sufficient precision.
- b. Automatic 3D-Scanner on a robotic arm.
- c. Automatic 3D-scanner on a reciprocator.

Inspection Ext.A1.- External measurement of the piece.

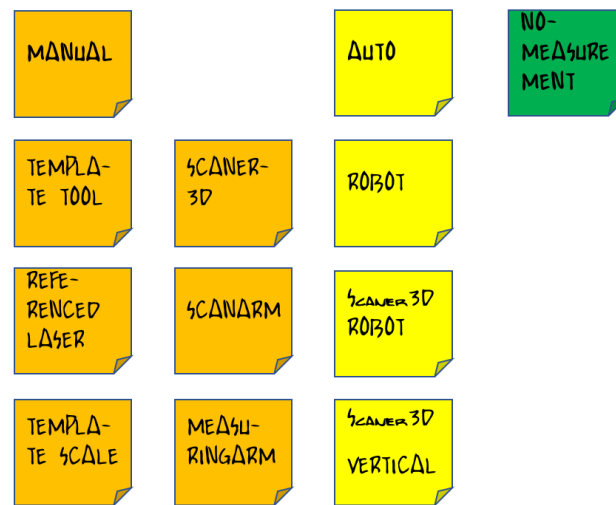
Manual measurement on a template is feasible, but complex to design and belongs to an outdated technology, although feasible under some conditions and, above all, better than the previous totally manual measurement, which stop down the machine in its internal process.

One of the solutions proposed is LASER-3D²⁶ scanning. In the case of manual scanning, it offers details that might not be sufficient²⁷. But there is the possibility of performing the scanning on a bench, robot and / or automatic reciprocator (for example: up and down movement around the piece in a circular way), but also on a manual or automatic arm. These solutions are being used for the validation of first pieces in the automotive sector²⁸.

²⁶ SCANNER-3D: Por ejemplo, la empresa Artec3D realiza este tipo de Scanner-3D: <https://www.artec3d.com/es>
<https://www.artec3d.com/>

²⁷ La tecnología actual de escáner en 3D portátiles ofrece tolerancias de 0,1mm cuando la mecanización podría requerir tolerancias del orden de 0,01mm (10 μ), y dependiendo de los usos, incluso superiores.

²⁸ GOM: <https://www.gom.com/metrology-systems/atos.html>



But there are also solutions on the market based on probe arms, laser and automatic robotic arms. In the links at the bottom of the page you can see a very simple application of a probe arm for application in automotive and body shops²⁹, so its price may not be too high.

Another solution in high precision manual probing arms is also on the market from several manufacturers³⁰ as you can explore in the links. These developments may or may not have been studied in the previous phases of the state of the art. Thus, each new state "B" or "C" carries a new study of the state of the art in order to know the real possibilities of that state or if it requires a particular subsequent development.

The option of anthropomorphic robotic arms such as probes or 3D-scanners would correspond to parts with a high cadence or high value-added pieces as molds or dies. It is also feasible, in this case, due to the great added value of the part that we consider in this example.

Experimentation Ext.A1.- External measurement of the piece.

In this phase we would have to evaluate the available factors, such as budget, cadence, required precision, the data transfer process and the availability of training and lateral support elements, and eliminate the options outside the budget range.

For example, in this case, we could eliminate the option of anthropomorphic robots, because we could not have enough cadence or the price of the part could not justify this investment. As well as the option of manual measurement on templates due to lack of precision and slowness, as well as possible errors in the transcription of the information to the machine tool.

We do not consider the transfer of the data in this workshop, because it would be part of another development workshop. At the moment, we could even consider a manual transfer that does not paralyze the machine to gradually improve with the inclusion of some kind of software that updates our CNC programs automatically.

It is important that this above limitation, determined in the Inspection and Experimentation phase, is not seen as an unsolvable problem in the Design-Thinking workshop despite the fact

²⁹ CELETTE: <https://www.celette.com/our-products/measuring-systems/naja-3d/>

³⁰ FARO: <https://www.faro.com/es-mx/productos/3d-manufacturing/faroarm/>

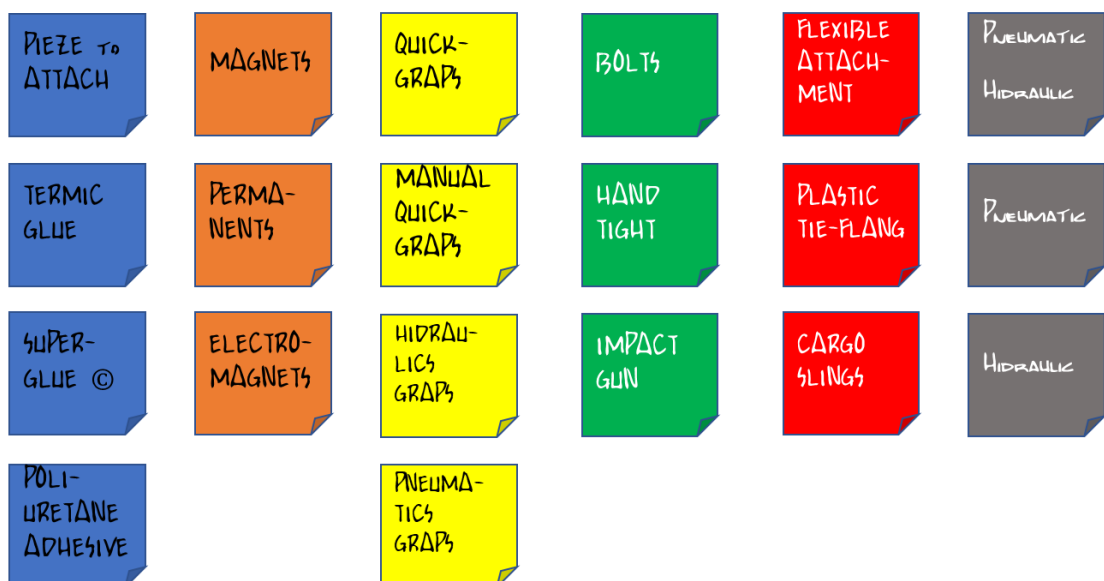
KREON: <https://kreon3d.com/es/brazo-de-medicion-mm-portatil/baces/>

that the team does not have the skills to carry it out. If the solution exists or can be developed, that is precisely the main reason for this SMED workshop under *Design-Thinking*

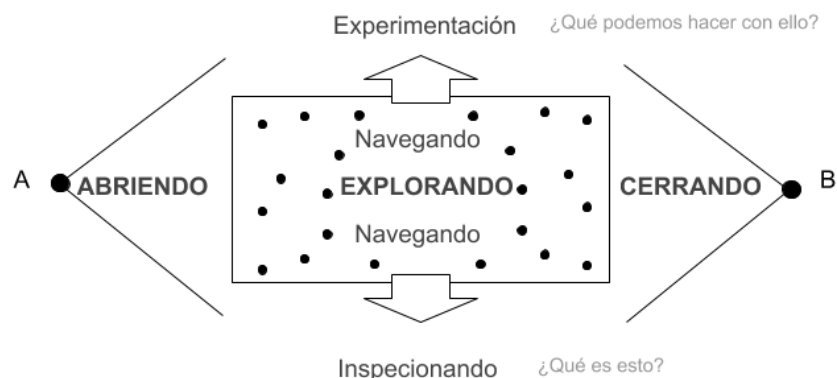
Process Ext.A2: Quick external clamping of the piece.

Navigation / Exploration Ext.A2.- Quick external clamping of the part.

- B-1) Glue the part.
 - a. American tape.
 - b. Glue.
 - i. Thermal Glue.
 - ii. Super-glue ©.
 - iii. Polyurethane adhesive.
- B-2) MAGNETS.
 - a. Permanent Magnets.
 - b. Electro-Magnets.
- B-3) QUICK-CLAMPS.
 - a. Manual Quick-Clamps.
 - b. HYdraulic Quick-Clamps.
 - c. Pneumatic Quick-Clamps.
- B-4) BOLTS OR NUTS.
 - a. Torque impact driver (**Actual Solution**).
- B-5) FLEXIBLE SUPPORT.
 - a. Load slings.
 - b. Plastic ties.
- B-6) PNEUMATIC OR HYDRAULIC CLAMPING
 - a. Pneumatic...
 - b. Hydraulic



Now let's imagine that we take the state **B-1-i: GLUE THE PIECE** using **THERMAL GLUE** as ridiculous as it may seem at first, and we delve into it exploring, inspecting and experimenting ...



Inspection Ext.A2.- Quick external clamping of the part.

We know, because "we are somewhat knowledgeable about the operation of thermal glue applications" that traditional thermal glue does not have sufficient adhesion strength for this application, although we could test it in this phase, for other types of applications. But, we can also do something that will lead to surprising results, which is to search for this pun on the Internet browser.

Thus, we open the traditional thermal glue and close it, discarding it. But this has led us to another "B" state that could give us the fast and flexible mooring result we are looking for.

Surprisingly, when we place **Adhesion + Clamping + Machining**³¹, as keywords in the search the image of a polymer appears with a revolutionary solution in this regard: <http://www.fgrip.eu/>

We also know that some heavy-duty adhesion applications are activated by UV rays or, by temperature, such as some epoxy resins. So, it could be another avenue of exploration and navigation.

Experimentation Ext.A2.- Quick external clamping of the part.

We have found a commercial solution for the adhesion based on polyurethane discs, now we have to check if the adhesion force and the usage requirements are adapted to our product through theoretical experimentation. Practical experimentation is also ruled out in this case for safety reasons.

As for alternative UV-activated polymeric adhesives, they have the problem that they are not easily removable so we would have to discard them for now. Just as ultraviolet rays may not work with steel opaque parts. However, those that can be activated by heat, we could bequeath to use them, but we find another problem that is the heating of the piece or the area to be removed, which could generate greater inconveniences than solutions and, the state of the art for this application. The application is not very evolved, so for the moment, it represents a dead

³¹ <http://www.fgrip.eu/> <https://www.interempresas.net/Aeronautica/Articulos/251937-El-sistema-de-amarre-F-GRIP-cumplira-con-las-necesidades-del-sector-aeronautico.html>

end that could be taken up again in the future. Thus, practical experimentation is required in safe conditions.

Process Int.A3: I/O – Evaluation and evacuation of the already processed part and placement of the new one, in the work area, in less than 10 minutes.

Here we have a particularly broad challenge and with very different variables, given the variability in the morphology and dimensions of the parts to be machined. This is the only work that we have a clear time limitation and, that will be the limitation in the inspection, placement and evacuation phases of the part.

Previous development of "A" state: Study of the technique

Zero-point placement

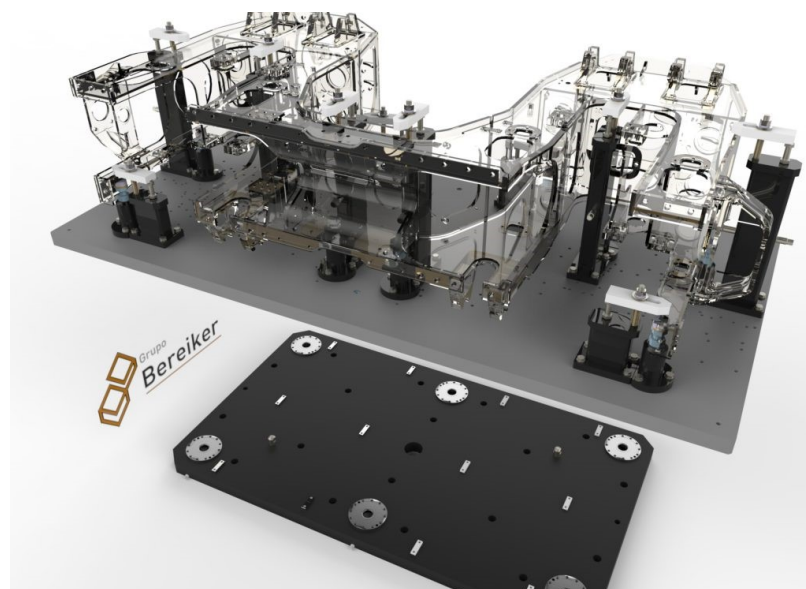


Figure 3: Zero-point clamping system.

Placing the part on a support that gives us the zero point of the part with sufficient precision is an industrial process for which we have already designed many commercial alternatives that we must know before trying to design our own solution of any kind.

Having studied deeply the process previously, we know the requirements of this particular process and its links with the remaining internal and external operations.

For example, there are zero-point pneumatic supports on the market such as the one shown in Figure 3³² that allow the change of support in seconds, outsourcing all pre and post measurement operations. The design exercise focuses on the way to place the piece on this support, so that it is always in an equal situation and ready for machining and the movement of the support and evacuation of the previous one that we will see below.

³² Zero-point pneumatic system: <https://www.bereiker.com/es/util-amarre-rodajes/>

Unfortunately, we cannot ensure that the type of part is always the same and that we place it on the support ready to be machined due to the variability of the parts to be machined, in this case. It is for this reason that the previous measurement processes and the establishment of the zero-point with respect to the support are so important.

Input/Output

The mistake we can make is to maintain the use of the overhead crane with this type of device. The inefficiency and unsafe by handling this device are great limitations. Here we may have to imagine new somewhat more efficient handling devices and run a Design-Thinking workshop for this question. However, it may also be a good exercise to maintain the gantry-crane, for the moment, because the alternative may require too significant an investment in the first phase.

For example, the most modern SMED systems work on rails with an entry position and another exit position of the press die. But suppose that due to the layout of the machine we cannot design this solution at the moment. So, we have to imagine other alternatives that are viable, fast and precise for the moment for the evacuation and placement of the new zero-point support. And we also have to investigate the state of the art for this new state "A".

Navigation/Exploration Int.A3.- Evacuation and placement in less than 10 minutes.

Once we have studied the state of the art of zero-point supports we can start with the Design-Thinking workshop to determine the medium in which we place this zero-point support on the machine.

Likewise, if these zero-point quick-change supports did not exist, we would have to have developed another "A" state to determine solutions for this problem. But, fortunately, it is a problem that the state of the art allows us to easily solve.

As an example, we have made a division based on the handling system, but the affinity diagram that separates between Manual or Automatic systems could also be valid.

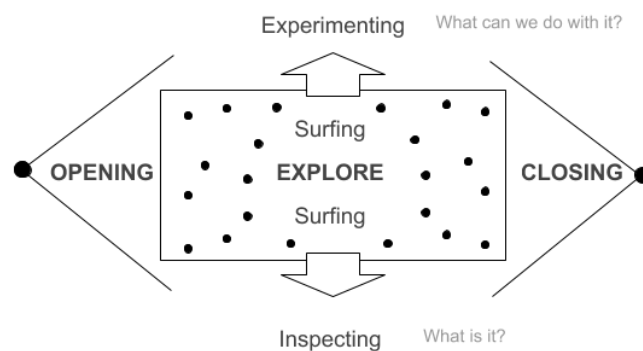
- B-1) DRONE;
- B-2) GANTRY-CRANE;
 - a. Automatic positioning system;
 - b. Manual positioning system;
- B-3) RAIL
 - a. Input and output on the same side;
 - b. Input and output on different side;
- B-4) FORKLIFT
 - a. Light electric forklift;
 - b. Diesel/Gas;
 - c. Wheel-Manual lifting system;
 - d. Mix Wheel-Electric/Manual Lifting system;
- B-5) WEIGHLESS MANIPULADOR;
 - a. Pneumatic Manipulator;
 - b. Hydraulic Manipulador;
- B-6) ROBOT;
 - a. Anthropomorphic-Manipulador Robot;
 - b. Robot / manipulator system designed for this purpose.

There is a process that greatly influences the fulfillment of the main time requirement that we have set and that can also be the subject of another Design-Thinking session and is the evaluation of chips and coolants, if exist.

Cleaning them can be an internal process that requires the machine to stop for long time. However, it will not be studied in detail now and it is up to the reader to apply the techniques outlined here to imagine new ways to carry out this activity quickly and effectively: blowing, vacuuming, dragging, gravity, etc.

In the process of opening, exploring and closing these “B” states, we can realize, as we mentioned before, that we do not have to change yet, or in this first approximation, the method of placement and evacuation of the zero-point support or that the investment required exceeds the benefits to be obtained in saving time.

We can also realize that with an adequate standardization and maintenance of the state of order and cleanliness (5S + 4R) of the environment, we can save enough time to meet the required change time in less than ten minutes.

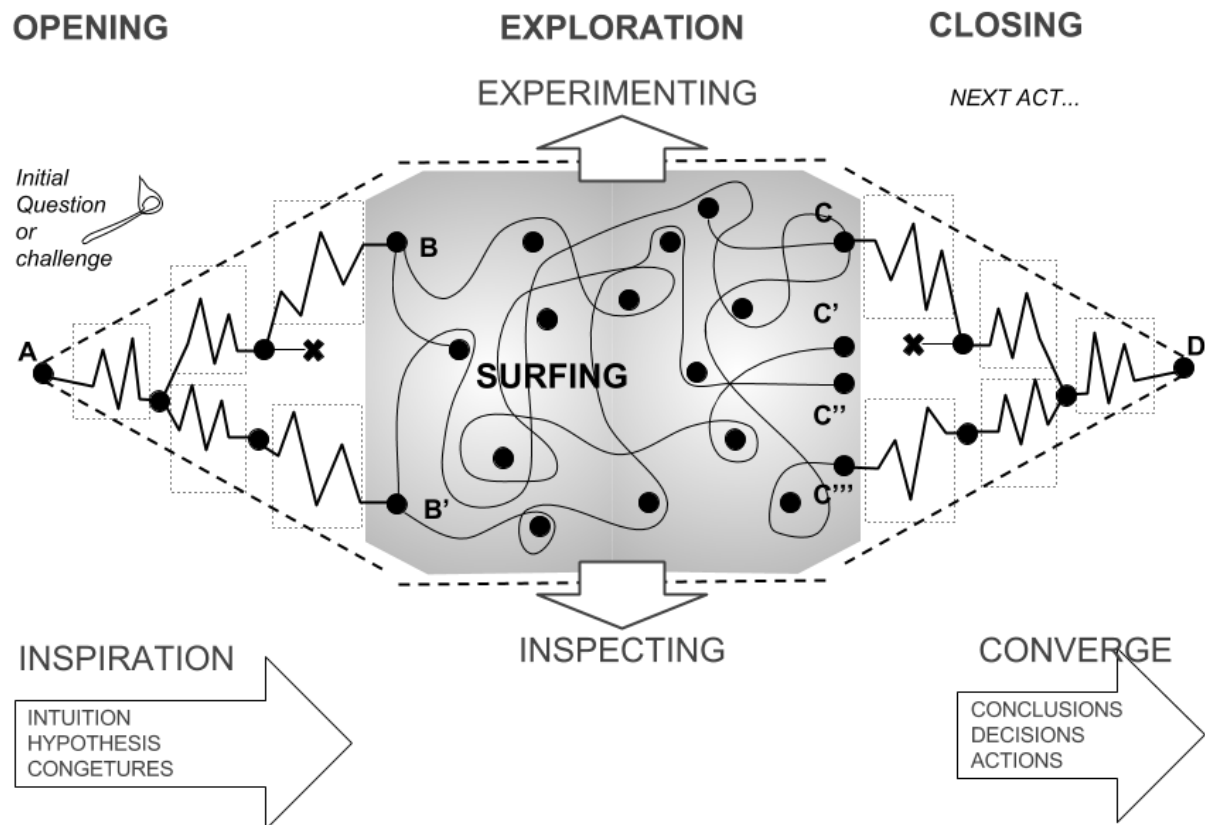


We still have a lot of work on OPENING + EXPLORATION (Navigation + inspection and experimentation) + CLOSING in this phase in each of the "B" states considered to reach new "C" stated. Its development will not be discussed here because it is redundant with those already exposed.

For example, status B-5: WEIGHTLESS MANIPULATOR, Hydraulic manipulator. We can explore different ways of moving the weightless manipulator: By means of rails, rotating arm, electric system with wheels, Manually, etc. Each and every one requires the previous three steps based on Design-Thinking methodology.

Act Three

CLOSURE - CONCRETION - DETAIL - ELIMINATION - IMPLEMENTATION - CONVERGENCE - ACTIONS -
MANUFACTURING - MINIMUM VIABLE PRODUCT - WORK PLAN.



Concretion

We specify the most profitable, fastest and easiest to implement solutions among all those studied. And given the technical limitations of the case studied and the eliminations that we have made among the non-viable options, it is not necessary to apply special techniques to determine the best options among those studied. The group will easily know the best options and their requirements if the previous phases have been developed in depth.

3P

In this act we would prototype the solutions using 3P. And thus, we could simulate rails for a quick change of the support, simulate the adhesive and the necessary tools and the probe arms, as well as the information transfer processes and the introduction of the necessary data in the machine tool. We would also standardize operations through the DPCC to detail the process and debug possible failures through an analysis of them and possible solutions: FMEA³³ or through a risk analysis (ISO-31000).

³³ FMEA: https://en.wikipedia.org/wiki/Failure_mode_and_effects_analysis

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https://es.wikipedia.org/wiki/An%C3%A1lisis_modal_de_fallos_y_efectos

IX. Annex A: ³⁴ Large machining: new clamping and positioning technologies

The Intefix³⁵ project aims to improve the productivity of machining processes and strengthen the industry of high added value products

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This article presents a global vision of the current needs and trends related to large machining. It describes the new technologies of tooling systems and the importance that these are acquiring in the control and monitoring of the manufacturing process. There is also a brief review of machine tools such as vertical lathes and large milling machines where the machining of large components is carried out.

Mechanization by sectors such as aeronautical, energy, wind and marine sectors often involves the use of large machine tools and auxiliary equipment such as tools for fixing and positioning the parts. Due to the large size of the parts that are manufactured in these sectors, it is common to use sophisticated clamping systems and monitoring of the machining process for their correct manufacture.

Tooling, positioning and monitoring systems

The fixing and positioning systems industry has developed notably in recent years and it is estimated that for 2018 it will exceed 70,000 million euros. This is mainly due to a higher demand from industries such as aeronautics, energy and wind power.

The Intefix project is located in this scenario, led by IK4-Tekniker³⁶ and financed with 7.5 M euros by the VII Framework Program of the European Union, which aims to improve the productivity of machining processes and strengthen the manufacturing industry. high value-added products.

One of the leading companies in fixing and positioning systems, which also participates in the Intefix project, is Bereiker³⁷, where various custom tools are designed and manufactured, according to customer requirements. Often these tools are designed for large parts which are manufactured by machining processes such as turning and milling in which very narrow dimensional tolerances have to be maintained, this forces the machining process to be meticulously controlled.

³⁴ Interempresas.net: <https://www.interempresas.net/MetalMecanica/Articulos/158132-Grandes-mecanizados-nuevas-tecnologias-de-fijacion-y-posicionamiento.html>

³⁵ INTEFIX: <https://portal.effra.eu/project/1088>
<http://www.intefix.eu/>
<https://cordis.europa.eu/project/rcn/109694/factsheet/en>

³⁶ IK4-Tekniker : <https://www.tekniker.es/es>

³⁷ Bereiker : <https://www.bereiker.com/es/soluciones-automatizacion-industrial/>

But not only the machining process has to be developed and improved, also the fastening systems are of great importance during the manufacture of the components. The latest developments in positioning and lashing systems already stand out for performing functions beyond their main purpose.

Normally the main functions of the tools are to hold and position the part, considered as a non-deformable body, but today the high precision required and the need to increase the performance of the manufacturing processes, forces to develop tools taking other aspects into account very different. Precision aspects such as deformations, vibrations and distortions in the workpiece during machining as a consequence of variations in the behavior of the machine-tool-part system throughout the process.

It also seeks to reduce the process times to the minimum possible, designing tools that facilitate machining in a single bundle and reduce the transfer times of the component between the different machines or stations where an operation is going to be carried out on the piece. For this, different fixing methods have been developed, such as hydraulic, magnetic, vacuum systems or the so-called 'zero point' system.

Regarding the design and manufacture of hydraulic / pneumatic systems, we can highlight the CMS company, which builds flexible clamping tools for machining sheet metal or carbon fiber aeronautical parts.

Depending on the part to be machined, the tooling adapts automatically to the geometry of the part through the numerical control of the machine tool. As they are components with complex geometry, this type of positioning system considerably facilitates machining.

Likewise, 'zero point' fixing systems are characterized by the rapidity of changing tools or parts, thus reducing change times and avoiding machine downtime. By means of this system a repeatability of ± 0.005 mm is obtained, offering a clamping force of 60,000 N, which makes it suitable for 5-axis machining where operations with large overhangs are common. In addition, it is applicable in different types of processes and machines.

On the other hand, the use of magnetic systems for fixing components is well known and continues to be one of the most widely used solutions by many steel machining industries. Companies such as Tecnomagnete³⁸ develop clamping equipment with which a great clamping force can be obtained, leaving 5 faces of the piece free. These systems offer an easy and fast positioning of the pieces with the consequent reduction of downtime, as well as practically nonexistent maintenance.

Another function that is currently being implemented in the so-called intelligent tools is the monitoring of the machining process. When machining thin bodies, narrow walls, materials with low machinability ... it is common to find problems of dimensional distortions, vibrations and tool breakage. This problem is especially true when it comes to components with high added value in the last stages of manufacture, as any failure is a great waste of money. Therefore, the use of tools that offer monitoring of the machining process allows control over the machine-tool-part system.

The sensorisation most commonly used in intelligent tools is based on the acquisition of machining efforts using piezoelectric or dynamometric systems, temperature monitoring using thermocouples,

³⁸ Tecnomagnete: <http://www.tecnomagnete.com/>

control of the tightening torque of the tool fixing elements and accelerometers for the detection of possible vibrations that result in machining failures or highlight harmful working modes for machines.

All these technologies that are currently being implemented in clamping systems for large and high added value parts can be the difference between having a good part the first time or having to dispose of the component, in many cases in the final stages of its manufacturing, with the consequent loss of money.

Vertical lathes and large milling machines

Large components: Tractor sectors in our environment

There are several sectors in our environment that focus on the manufacture of large components. As examples of tractor sectors we can highlight the aeronautics, the wind and energy sector, the oil & gas sector and also others such as the automotive and rail sectors, although on a smaller scale in terms of size. These sectors are characterized by working with large components, but with very tight dimensional tolerances.

In some components of the wind power sector, shape accuracies of a few hundredths are sought for components with a diameter of more than 2,000 mm. This fact makes manufacturing extremely difficult and makes it a significant challenge for both machinists and machine tool manufacturers, going through the entire supply chain (tool manufacturers, tooling, programmers, verification, etc.). In the case of sectors such as aeronautics, the problem is accentuated when working with materials with very low machinability, such as heat-resistant superalloys such as Inconel³⁹, Waspaloy⁴⁰, and others.

Large vertical lathes

The sector of manufacturers of large vertical lathes has come a long way in recent years. Some manufacturers go as far as manufacturing machines up to 10,000 mm in table diameter with maximum turning diameters of up to 14 meters. These machines, in addition to having the most advanced technology available, have extensive experience gathered by manufacturers in terms of work capacities and production requirements.

The keys to achieving high performance over time in this class of machines are mainly the high structural rigidity and the extraordinary technological capabilities they include. Some of the most recognized manufacturers worldwide in this sector are Pietro Carnaghi⁴¹ and Waldrich⁴².

Closer in our environment we also find important manufacturers of large vertical lathes and multitasking centers. Some examples are cited below. In the case of Bost⁴³, highlighting the great

³⁹ INCONEL: <https://en.wikipedia.org/wiki/Inconel>

⁴⁰ WASPALOY: <https://en.wikipedia.org/wiki/Waspaloy>

⁴¹ Pietro Carnaghi: <https://www.pietrocarnaghi.it/es/index.html>

⁴² Waldrich: <https://www.waldrich-coburg.de/en/>

⁴³ Bost: <http://www.bost.es/es/>

flexibility in the design of machines that allows solutions to the particular needs of each sector or client, always at the lowest cost and with the highest possible quality.

Another clear example is GMTK⁴⁴ with large vertical lathes and multitasking centers that allow machining solutions that improve the efficiency and profitability of the users of its machines. Danobat⁴⁵, a well-known machine tool manufacturer, also has extensive experience in the design and manufacture of large lathes. This company has become a benchmark in turning, its machines work in many leading companies in various sectors and are characterized by being highly advanced and high-performance machines.

Machining centers: precision in large dimensions

Manufacturers such as Zayer⁴⁶ should be highlighted in this line. With machines like Arion⁴⁷, the milling machine 4.0, this company is further consolidated as a specialist manufacturer in milling technologies.

This machine, presented at the 2016 Machine Tool Biennial stands out for its 4.0 connectivity and its 30^º millesimal head that can be interpolated in 5 axes.

Juaristi⁴⁸ manufactures large machining centers, with a wide range of heads and a high level of automation. Its machines are capable of machining large parts, some up to 6,000 mm in length and more than 20,000 kg in weight. Another reference manufacturer of large milling machines and machining centers is DMG MORI⁴⁹. Its advanced production solutions guarantee an important competitive capacity. Another of the key characteristics of its products is its specific orientation to the sector, focusing its efforts mainly on the aerospace, automotive, mold and tool manufacturing sectors. In fact, this manufacturer has an Aerospace Center of Excellence capable of serving the market with innovative turnkey solutions; an HSC Center and Mold Laboratory established after many years of experience, as well as a department of individual solutions for the large-scale production of automotive components.

Use of 'high performance computing' and monitoring of machine tools to improve competitiveness

Among the future strategies of the European industry is the search for greater competitiveness through process optimization and cost reduction. In the coming years, a strong transformation of conventional manufacturing processes will be required from the use of Information and Communication Technologies (ICTs) and advanced manufacturing, with new generations of tools for the simulation of industrial processes.

On the one hand, it is necessary: 1) the revision and reorientation of the traditional prediction models, useful for the study of local problems (forced vibrations, chatter, wear, etc.) and 2) the

⁴⁴ GMTK: <http://www.gmtk.es/es/>

⁴⁵ DANOBAT: <https://www.danobatgroup.com/es>

⁴⁶ Zayer: <https://www.zayer.com/es/>

⁴⁷ AIRON: <https://www.arionmachine.com/>

⁴⁸ JUARISTI: <https://juaristi.com/es/>

⁴⁹ DMG MOR: <https://es.dmgmori.com/>

overcoming of the limits of the CAM-software, focused solely on the geometric simulation, without other consideration. To overcome the problems of both, a unique and transversal solution to these two worlds must be sought, which incorporates the best of each one. This solution involves incorporating complex geometries and trajectories into traditional simulation models, which do incorporate material characteristics and modal parameters. This increases the complexity of the models and computational needs, for which High Performance Computing must be used. With this, another strong idea of this approach is ensured, such as the fact that the results of the simulations are available almost immediately.

Furthermore, the intensive monitoring of the process variables through semi-autonomous equipment is intended. A very interesting solution is to place a reconfigurable monitoring box in the machine cabinet for the measurement of process variables. This equipment can monitor for hours and periodically upload the data to a central server to transmit the data to certain personal positions from there. Thus, quasi-online analysis is allowed while recording continues. It is not difficult to imagine a flat where each machine has its own monitoring unit and all of them are slaves to a master chassis.

The final objective would thus be to narrow models and reality that, traditionally, has been the great deficit found to transfer innovations and developments in the field of simulation to the real environment.

Finally, to handle this huge amount of information, the development of new applications must be tackled using the cloud and techniques such as Big Data. The transport of data, the management of internal networks and the guarantee of security and confidentiality will be complementary challenges no less important for the use and integration of the cloud in the industrial environment.